VOLUME XL NUMBER 1

BOTANICAL GAZETTE

JULY, 1905

UNDESCRIBED PLANTS FROM GUATEMALA AND OTHER CENTRAL AMERICAN REPUBLICS. XXVII.[1]

JOHN DONNELL SMITH.

Porceiia stenopetala Donn. Sm.—Folia maxima obovato-oblonga vel oblonga subcaudato-acuminata basi obtusiuscula vel rotundata supra glabra subtus pubescentia, nervis crebris parallelis subrectis. Pedunculi ex ligno vetere prorumpentes fasciculati vel approximati. Petala linearia multoties longiora quam latiora.

Arbor, ramulis petiolis gemmis pedunculis floribus fusco-velutinis. Folia papyracea, juniora obovato-oblonga, provectiora oblonga 26–31^{cm} longa 8–9^{cm} lata basi saepius rotundata, nervis lateralibus utrinque 15–17, petiolis vix 5^{mm} longis. Inflorescentia tantum in trunco (*de Tuerckheim* in schedula) vel in ramis crassis defoliatis obvia, pedunculis 8–15-subaggregatis 1.5–2^{cm} longis. Sepala deltoidea vix 3^{mm} longa patentia intus glabra. Petala imbricata aequalia utrinque pubescentia atropurpurea 6–6.5^{cm} longa 4–5^{mm} lata acuta. Stamina numerosissima cuneato-quadrata 1^{mm} longa compressa. Torus hemisphericus. Ovaria 9–12 oblonga 3–4^{mm} longa inflata sericea, stigmate sessili capitato, ovulis biseriatis 8–12. Bacca ignota.—Ad *P. Nicaraguensem* Benth. et Hook. staminibus ovariisque arcte accedens inflorescentia petalisque longe distat.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Mart. 1904, *von Tuerckheim*, n. 8496 ex Pl. Guat. etc., quas ed. Donn. Sm.

Ionidium Thiemei Donn. Sm.—Fruticosum nanum pubescens. Stipulae minutae. Folia alterna ovalia apice rotunda in petiolum angustata crenulata. Pedunculi singuli foliis breviores uniflori. Petalum inferum sepalis subaequalibus integris altero tanto longius, lamina suborbiculari.

Caulis e rhizomate prostrato ascendens 3–6^{cm} altus lignosus parce ramosus cum petiolis pedunculisque ferrugineo-pubescens. Folia approximata 23–27^{mm} longa 17–19^{mm} lata supra pilis conspersa subtus nervatione pubescentia, petiolis

[1] Continued from BOT. GAZ. **37**: 423. 1904.

circa 5^{mm} longis, stipulis lineari-lanceolatis 1–2^{mm} longis persistentibus. Pedunculi capillacei 12–16^{mm} longi. Sepala ovato-lanceolata 3^{mm} longa pubescentia. Petalum inferum 6^{mm} longum basi gibbosum, lamina unguem oblongam aequante, ceteris oblongis nervosis. Antherae subsessiles in annulum connatae, membrana terminali semiorbiculari. Capsula glabra.

San Pedro Sula, Depart. Santa Bárbara, Honduras, alt. 400^{m}, Jun. 1888, *C. Thieme*, n. 5628 ex Pl. Guat. etc., quas. ed. Donn. Sm.

Rourea Hondurensis Donn. Sm. (§DALBERGIOIDEAE Planch.)—Folia 4–5-juga, foliolis discoloribus marginatis supra glabris subtus pubescentibus obovato- vel elliptico-oblongis apice rotundis vel subacuminatis basi rotundis vel acutiusculis, infimis orbiculari-ovalibus. Paniculae folia subaequantes breviter parceque ramosae, pedicellis brevissimis. Capsula castaneo-velutina bis longior quam crassior.

Frutex scandens ut videtur, ramis petiolis paniculis ferrugineo-pubescentibus. Petiolus 2–3.5^{cm} longus, folii rhachi 6–8^{cm} longa, foliolis subcoriaceis aequilateralibus ad costam et nervos laterales utrinque 6–9 subtus ferrugineis, terminali obovato-oblongo 4.5–7^{cm} longo 2–3^{cm} lato brevissime acuminato basi acuto, lateralibus oppositis per paria deorsum decrescentibus 3.5–5^{cm} longis 1.5–2^{cm} latis utrinque rotundis vel basi subacutis, infimis 22^{mm} longis 17^{mm} latis. Paniculae singulae aut binae 8–13^{cm} longae, ramis simplicibus 0.5–1.5^{cm} longis. Calyx fructiferus glaber partitus pedicellum subaequans, laciniis ovatis 3^{mm} longis. Capsula valde arcuata 1.5^{cm} longa, semine optime ovali quam arillus bis longiore. Flores deficiunt.

Ad ripas rivuli prope Puerto Sierra, Honduras, Jan. 1903, *Percy Wilson* (n. 240).

Machaerium Verapazense Donn. Sm. (§RETICULATA Benth.)—Scandens inerme. Folia petiolo subdimidio longiora, foliolis 5 rotundo-ovatis vel ovalibus utrinque obtusis supra glabrescentibus subtus puberulis. Racemi solitarii petiolos subaequantes, pedicellis pluri-fasciculatis quam flores parum brevioribus. Stamina monadelpha. Ovula 2–4.

Caulis ramosus cum petiolis glabrescens, stipulis aristulato-lanceolatis 2–3^{mm} longis. Folia petiolo 3–6^{cm} longo addito 8–15^{cm} longa, foliolis papyraceis discoloribus costa excurrente mucrunculatis 6–7-penninerviis subtus tenuiter reticulatis, lateralibus oppositis 4–5.5^{cm} longis 2–3.5^{cm} latis basi rotundis vel levissime retusis, petiolulis incrassatis 3^{mm} longis, foliolo terminali maximo 5–6.5^{cm} longo 3–4.5^{cm} lato basi obtusiusculo, petiolulo 1–1.5^{cm} longo. Racemi axillares simplices fulvo-pilosi e basi floriferi 3–7^{cm} longi, pedicellis 3–12-nis 4–5^{mm} longis, bracteolis lineari-lanceolatis 2–3^{mm} longis, floribus violaceis, ut videtur, 6–7^{mm} longis. Calyx ecalyculatus pubescens hemisphericus 2^{mm} altus truncatus mucrun-

culo-denticulatus. Petala subaequilonga unguibus ciliata, vexillo orbiculari extus cano-sericeo. Stamina omnia in vaginam totam fissam usque ad duas partes connata 5^{mm} longa, antheris versatilibus. Ovarium cano-sericeum clavato-lineare 5^{mm} longum in stipitem 1^{mm} longam disco brevi circumdatam attenuatum, dimidio inferiore 2-vel 3-vel plerumque 4-ovulato, dimidio superiore applanato vacuo, stylo decurvo 2^{mm} longo. Legumen ignotum.—Species ovulis anormalis.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jan. 1904, *von Tuerckheim*, n. 8508 ex Pl. Guat. etc., quas ed. Donn. Sm.

Pithecolobium macrandrium Donn. Sm. (§CHLOROLEUCON Benth.)—Pinnae 10–17-jugae, foliolis 16–40-jugis. Pedunculi ad axillas singuli ad apicem ramulorum racemosi et fasciculati spicis elongatis densissimis parum longiores. Stamina corollam calyce quinquies longiorem 5–6-plo superantia usque ad medium connata.

Arbuscula 5-metralis, ramulis angulatis uti rhachis foliorum et pedunculi glabrescentibus fuscis, aculeis stipularibus binis rectis 4–10^{mm} longis. Folia petiolo 3–8^{cm} longo addito 16–46^{cm} longa, glandula inter pinnas scutelliformi inter foliola stipitata, pinnis 5–12^{cm} longis, foliolis subsessilibus 9–18^{mm} longis oblongis apice obtuso apiculatis basi subtus glanduligera semicordatis supra praeter costam glabris subtus glaucis. Pedunculi 5–12^{cm} longi, spicarum rhachi 4–8^{cm} longa et floribus pubescentibus, bracteolis ovatis 2^{mm} longis intus glabris induratis spinula apiculatis calycem campanulatum triangulari-denticulatum aequantibus. Corolla infundibuliformis 1^{cm} longa usque ad primam tertiam partem lobata, lobis ovatis acutis. Stamina alba indefinita, antheris eglandulosis. Ovarium sessile pubescens. Legumina (juvenilia tantum suppetentia) oblonga leviter curvata plana.—Stamina magnitudine ea fere omnium aliarum specierum superant *Calliandram* referentia.

In silvis ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jul. 1902, Nov. 1904, *von Tuerckheim*, nn. 8193, 8667 ex Pl. Guat. etc., quas ed. Donn. Sm.

Miconia Hondurensis Donn. Sm. (§TAMONEA Naud.)—Fere glabra. Folia opaca lucida lanceolato-elliptica contracto-acuminata basi acuta integerrima triplinervia, venis transversalibus simplicibus rectis. Calyx subsessilis obconico-oblongus limbo subintegro dilatatus. Stamina glabra.

Ramuli ad apicem versus obtuse tetragoni cum gemmis petiolis pedunculis leviter fusco-furfuraceis. Folia subcoriacea in sicco utrinque viridia apice ipso obtusiuscula disparia, altero 13.5–15^{cm} longo 5–5.5^{cm} lato, altero 8–10.5^{cm} longo 3.5–4.5^{cm} lato, venis subtus conspicuis, venulis supra obsoletis subtus grosse reticulatis, petiolis canaliculatis 1–1.5^{cm} longis. Thyrsus terminalis et subterminalis paniculiformis pedunculo 2.5–4.5^{cm} longo adjecto folia subaequans laxiflorus, pedicellis vix ullis minute bibracteolatis, floribus saepius ternis 5-meris. Calyx viridis vix pulverulentus 3.5^{mm} longus 10-costatus, limbo membranaceo

undulato 0.5^{mm} lato. Petala siccitate simul flavicantia et rubescentia extus vix pulverulenta obovato-quadrata 4^{mm} longa retusa reflexa. Stamina disparia $7–9^{mm}$ longa, antheris filamenta paulo excedentibus falcatis, connectivo infra loculos haud producto basi antice biauriculato et ibidem rubiginoso-glanduloso. Ovarium pauciovulatum, stylo $8–10^{mm}$ longo, stigmate capitato. Bacca nondum visa.—*M. aureae* Naud. proxima.

Prope Puerto Sierra, Honduras, Febr. 1903, *Percy Wilson* (n. 575).

Miconia oinochrophylla Donn. Sm. (§SERIATIFLORAE Naud.)—Glabra. Folia lanceolata vellanceolato-elliptica superne subsensim acuminata basi acuta subtus vinicoloria et cretaceo-punctulata adjecto nervulo utroque submarginali 5-nervia margine denticulato setulifera. Thyrsi rami semel 2–3-fidi, floribus sessilibus.

Ramuli obtuse tetragoni. Folia in eodem jugo paulo inaequalia $6–25^{cm}$ longa medio $5–9^{cm}$ lata, setulis marginalibus rigidis, petiolis $2.5–6^{cm}$ longis. Thyrsus terminalis $8–10^{cm}$ altus, ramis primariis decussatis praeter infimos trifidos bifidis, secundariis divaricatis, fructiferis $1.5–2.5^{cm}$ longis sulcatis purpurascentibus, bracteolis deltoideis 1^{mm} longis ciliolatis, floribus secundis 5-meris. Calyx teretiusculus 2.5^{mm} diametiens ecostatus, ore subintegro. Petala late oblonga 3^{mm} longa asymmetrica apice saepius emarginata. Antherae lineares 2^{mm} longae filamenta aequantes uniporosae. Ovarium apice tantum liberum 5-loculare, stylo crassiusculo 3^{mm} longo. Bacca nigra 4^{mm} diametiens.

Prope Livingston, Depart. Livingston, Guat., Febr. 1905, *von Tuerckheim*, n. 8684 ex Pl. Guat. etc., quas ed. Donn. Sm.

HAMELIA PATENS Jacq., var. **coronata** Donn. Sm.—Calycis segmenta patentia oblonga 4^{mm} longa tubum aequantia obtusa ciliata ceterum glabra. Fructus segmentis calycinis paulo auctis persistentibus coronatus.

Folia plerumque quaterna glabrescentia axillis subtus barbata. Stipulae setaceae.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Aug. 1903, *von Tuerckheim*, n. 8532 ex Pl. Guat. etc., quas ed. Donn. Sm.

Hoffmannia calycosa Donn. Sm.—Glabrescens. Folia inter minora lanceolato-elliptica deorsim sensim superne contractius acuminata. Cymae aggregatae petiolo breviores densiflorae, pedunculis pedicellisque brevissimis. Calycis segmenta linearia tubo bis et ultra longiora patentia. Corolla rotata, segmentis calycem subaequantibus.

Suffrutex, ramis teretibus, novellis bifariam puberulis. Stipulae triangulares contracto-acuminatae 1^{mm} longae. Folia nascentia nervis subtus puberula,

provectiora glabra 9–15^{cm} longa 3.5–5.5^{cm} lata, nervis utrinsecus 6–8, petiolis glabrescentibus 8–15^{mm} longis. Cymae 6–10^{mm} longae, pedunculis pedicellisque 1–2^{mm} longis crassiusculis pilosiusculis, floribus tetrameris. Calycis pilosiusculi tubus obpyramidatus 2^{mm} altus tetragonus, segmenta 4–5^{mm} longa acuta carinata, sinubus parce glanduligeris. Corollae glabrae segmenta lineari-lanceolata. Stamina ori corollae inserta, antheris subsessilibus segmenta corollina fere aequantibus. Ovarium biloculare, stigmatis lobis liberis vix 0.5^{mm} longis. Bacca desideratur.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Maj. 1901, *von Tuerckheim*, n. 7912 ex Pl. Guat. etc., quas ed. Donn. Sm.

Hoffmannia lineolata Donn. Sm.—Rami crassi teretes glabrescentes. Folia maxima oblanceolato-elliptica acuminata in petiolum gracilem longe attenuata membranacea utrinque lineolata praeter nervos subtus ferrugineo-puberulos glabra. Cymae aggregatae petiolo 2–3-plo breviores pedunculatae cincinnales, pedicellis brevibus. Corolla rotata. Stamina sinubus corollinis inserta, antheris sessilibus.

Frutex, ramis digitum crassis fistulosis. Stipulae deciduae. Folia opposita 24–30^{cm} longa 6–12^{cm} lata discoloria cystolithis linearibus farcta subtus passim nigro-punctulata, nervis lateralibus utrinsecus 14–17, petiolis 3–7^{cm} longis. Cymae 1.5–2.5^{cm} longae quandoque semel vel bis dichotomae cum floribus 4-meris ferrugineo-puberulae. Calyx 2^{mm} altus pedicellum subaequans, limbo sinuato-dentato. Corollae tubus cylindricus 2^{mm} longus, segmenta linearioblonga 4^{mm} longa acuta. Antherae 3^{mm} longae. Ovarium biloculare, styli antheras paulo superantis lobis connatis 1^{mm} longis. Fructus globularis rubropunctatus, seminibus rubellis.

Cubilquitz, Depart. Verapaz, Guat., alt. 350^{m}, Maj. 1902, *von Tuerckheim*, n. 8227 ex Pl. Guat. etc., quas ed. Donn. Sm.

Psychotria pleuropoda Donn. Sm. (§MAPOURIA Benth.)—Praeter stipulas bracteas bracteolas ferrugineo-ciliolatas glaberrima. Folia lineari-lanceolata internodiis multoties longiora. Stipulae majusculae connatae bifidae, laciniis lineari-setaceis. Pedunculus axillaris gracillimus. Cyma pedunculi dimidium subaequans pyramidalis, ramis ramulisque quaternis, floribus confertis. Corollae lobi tubo subaequilongi.

Suffrutex metralis dichotomo-ramosus, internodiis 1–3^{cm} longis. Folia 12–18^{cm} longa 2–2.5^{cm} lata utrinque deorsum autem longius attenuata, venulis subobsoletis, petiolis 5–10^{mm} longis. Stipulae utrinque solitariae in vaginam plus minus connatae 10–13^{mm} longae, parte inferiore ovata herbacea laciniis fuscis parum longiore. Pedunculi ex axillis perpaucis orti 7–8^{cm} longi, fructiferi reflexi. Cymae rami complanati, infimi 1.5^{cm} longi, pedicellis 0.5–1.5^{mm}

longis, bracteis bracteolisque minutis, floribus 5-meris glabris. Calyx bracteolatus campanulatus ultra ovarium productus 2^{mm} altus, lobis ovatis 0.5^{mm} longis. Corollae tubus cylindricus rectus 3^{mm} longus, lobis oblongis $2.5–3^{mm}$ longis reflexis apice cucullatis. Stamina annulo cano-pubescenti 1^{mm} infra orem corollae inserta, antheris subsessilibus 1.5^{mm} longis. Stylus 5^{mm} longus. Fructus ovalis $5–6^{mm}$ longus, pyrenis 4-carinatis facie ventrali haud sulcatis.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Aug. 1903, *von Tuerckheim*, n. 8529 ex Pl. Guat. etc., quas ed. Donn. Sm.

Otopappus syncephalus Donn. Sm.—Folia perelongate oblongo-ovata acuminata basi subtruncata vel rotundata subtus setulosa. Paniculae pleistocephalae, capitulis discoideis inter minora 3–6-aggregatis sessilibus.

Rami validi cum petiolis paniculis capitulis leviter puberulis. Folia crassa subintegra $12–17^{cm}$ longa $4.5–6^{cm}$ lata supra scabrida subtus setulis scabriuscula, petiolis $1.5–2^{cm}$ longis. Paniculae foliis breviores, capitulis $5–6^{mm}$ altis et diametientibus 15–20-floris, involucri 3^{mm} alti bracteis 4-seriatis ovalibus obtusis scariosis, paleis oblongis acuminatis exappendiculatis parce puberulis, corollae 3^{mm} longae limbo semifido tubum bis superante, acheniis unialatis, pappo paleaceo. —*O. robusto* Hemsl. proximus.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Apr. 1904, *von Tuerckheim*, n. 8694 ex Pl. Guat. etc., quas ed. Donn. Sm.

Echites Cobanensis Donn. Sm.—Folia lineari-lanceolata basi rotundata vel retusa subtus incano-tomentosa, nervis lateralibus crebris. Pedicelli graciles, bracteis minutis. Corolla calyce multoties longior, faucibus tubo bis brevioribus paulo latioribus. Antherarum appendiculae obtusae adnatae. Discus lobatus.

Folia discoloria supra uti caulis et racemi fusco-puberula $8–10^{cm}$ longa 1.5^{cm} lata superne sensim acuteque angustata, nervis lateralibus utrinsecus 18–22, petiolis $6–8^{mm}$ longis. Racemi $6–10^{cm}$ longi, pedicellis 1.5^{cm} longis, bracteis subulatis 2^{mm} longis. Calycis intus basi pluriglandulosi segmenta ovata 3^{mm} longa. Corolla 2^{cm} longa, tubo 16^{mm} longo, faucibus leviter ampliatis.

Cobán, Depart. Alta Verapaz, Guat., alt. 1400^{m}, Aug. 1904, *von Tuerckheim*, n. 8709 ex Pl. Guat. etc., quas ed. Donn. Sm.

Echites Rosana Donn. Sm.—Glabra. Folia subsessilia lanceolata cordata subtus albicantia et fusco-reticulata, nervulis basalibus utroque latere binis. Racemi foliis longiores, pedicellis gracilibus bracteas calycemque subaequantibus. Corolla hypocraterimorpha, tubo laciniis calycinis bis fere longiore medio staminifero. Antherarum appendiculae obtusae adnatae. Disci squamae distinctae.

Folia 7–12^{cm} longa 1.5–3^{cm} lata superne sensim acuteque attenuata vel sursum nervulis basalibus brevissimis, petiolis 3–4^{mm} longis. Racemi 12–16^{cm} longi, pedicellis 9–11^{mm} longis, bracteis lineari-lanceolatis. Calyx intus basi glandulosus, laciniis lineari-lanceolatis 7^{mm} longis. Corolla 2^{cm} longa, tubo subaequaliter cylindrico.

Buena Vista, Depart. Santa Rosa, Guat., alt. 1000^{m}, Apr. 1893, *Heyde et Lux*, n. 4540 ex Pl. Guat., etc., quas ed. Donn. Sm.

Rhabdadenia macrantha Donn. Sm.—Glaberrima. Folia coriacea oblonga apice rotunda et cuspidata basi acuta. Pedunculus gracilis biflorus. Calyx pedicello paulo brevior, segmentis oblongis apiculatis. Corolla amplissima, tubo calycem sesquiaequante faucibus bis breviore. Antherae acutae dorso superne barbatae. Disci squamae semiconnatae rotundatae.

Volubilis ut videtur, internodiis 2–5^{cm} longis. Folia juniora glaucescentia aetate provectiore nitida 7–9.5^{cm} longa 3–3.5^{cm} lata abrupte minuteque cuspidata, nervis supra impressis subtus tenuibus subarcuatis, venis minute reticulatis, petiolis 1.5–2^{cm} longis. Pedunculus ex axilla suprema ortus 3–4.5^{cm} longus, pedicellis binis 10–14^{mm} longis, bracteolis minutis triangularibus, floribus glabris. Calycis segmenta eglandulosa 9–10^{mm} longa 3.5^{mm} lata obtusa nervata reticulata. Corolla in herbario aurantiacea, tubo cylindrico 18^{mm} longo ad apicem plaga staminifera cano-hirsuto in fauces 3.5^{cm} longas sensim ampliata, lobis dolabriformibus 2^{cm} longis. Antherae lanceolato-linearis 4–5^{mm} longae, filamentis complanatis paulo longioribus quam latioribus. Disci squamae carnosae 1.5^{mm} longae ovaria sejuncta orbicularia aequantes, stylo 2.5^{cm} longo, stigmatibus apice penicillatis, membrana reflexa 1.5^{mm} longa. Folliculi ignoti. —*R. biflorae* Muell. Arg. affinis.

Ad ripas rivuli prope Puerto Sierra, Honduras, Jan. 1903, *Percy Wilson* (n. 244).

Marsdenia laxiflora Donn. Sm.—Glaberrima. Folia subcoriacea nitida lanceolata vel lanceolato-oblonga sensim vel abruptius acuminata ad basin obtusam supra pluriglandulosa. Inflorescentia uniaxillaris folia subaequans laxe cymosa, pedunculo ramis pedicellis filiformibus. Corolla subrotata. Coronae squamae gynostegium aequantes.

Suffruticosa volubilis ramosa. Folia 7–12^{cm} longa 1.5–3.5^{cm} lata, nervis lateralibus utrinsecus 7–9, petiolis 5–10^{mm} longis. Cymae flexuosae pauciflorae, pedunculis 4–6^{cm} longis, ramis 2–4^{cm} longis, pedicellis 2–4-nis basi minute pluribracteolatis 1–2^{cm} longis, floribus totis praeter calycis corollaeque margines ciliolatos glabris. Calyx prope sinus uniglandularis, segmentis ovatis obtusis 2^{mm} longis. Corollae tubus 2^{mm} longus, segmenta leviter obtegentia oblonga

7mm longa obtusa. Coronae squamae planae membranaceae sejunctae oblongo-ellipticae obtusae ad quartam partem liberae 3mm longae basi auriculatae. Pollinia erecta ovoidea. Discus stylinus pulvinatus. Folliculi ignoti.—Inflorescentia laxissima hanc speciem bene significat.

Ad Río Dolores, Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350m, Aug. 1903, *von Tuerckheim*, n. 8558II ex Pl. Guat. etc., quas ed. Donn. Sm.

Ipomoea Tuerckheimii (Vatke ined.) Donn. Sm. (§STROPHIPOMOEA, *Integrifoliae*, *Hastatae*. Peter in Engl. et Prantl Nat. Pflanzenfam. IV. 3a 30.)—Folia longe acuminato-cordiformia, lobis basalibus brevibus rotundatis, sinu acuto, margine subintegro vel sinuato-dentato. Pedunculi cymoso-pluriflori. Sepala aequalia dorso tuberculata. Corolla parva, limbo caeruleo.

Caulis cum petiolis et foliis novellis pubescens. Folia aetate provectiore praeter marginem glabrescentia 6–8cm longa 3.5–4.5cm lata mucrunculo apiculata usque ad quintam partem bilobata, petiolis 3.5–6cm longis. Pedunculi 2.5–3cm longi 2–7-flori. Sepala oblongo-ovata 4.5mm longa glabra, costa extus tuberculis rubris prominente. Corollae circa 2cm longae limbus fide cl. repertoris in vivo caeruleus. Capsula ovoidea 1cm longa breviter cuspidata bilocularis quadrivalvis, seminibus 4 vix puberulis.

Cobán, Depart. Alta Verapaz, Guat., alt. 1400m, Nov. 1886, *von Tuerckheim*, n. 386 ex Pl. Guat. etc., quas ed. Donn. Sm.—Cl. *Hallier* in Durand et Pitt. Prim. Fl. Cost. Fasc. III. 203 exemplum Tuerckheimianum sub nomine *I. Tweediei* Hook. incaute ut videtur citavit.

Brachistus physocalycius Donn. Sm.—Folia dimorpha, altero lanceolato-oblongo alterum ovale multoties superante. Flores gemini. Calyx subinteger, fructifer valde auctus. Corolla infundibularis quarta parte lobata. Filamenta filiformia antheris longiora. Bacca calyce tota inclusa.

Fruticosus. Folia disticha membranacea supra glabra subtus cum ramis petiolisque pubescentia, majore 16–22cm longo 5–6.5cm lato inaequilaterali sursum subsensim longeque acuminato basi inaequali plus minus acuto, petiolo 0.5–1.5cm longo, folio minore 1.5–6cm longo 1–3.5cm lato utrinque obtusiusculo, petiolo vix ullo. Pedunculi cernui 4–6mm longi. Flores toti glabri 12mm longi. Calyx campanulatus sub anthesi 3mm altus mucrunculo denticulatus. Corolla alba e basi paullatim ampliata, lobis ovatis erectis. Stamina 2mm supra basin corollae affixa, filamentis 3mm longis basi haud dilatatis, antheris oblongis 2mm longis. Stylus 9mm longus. Bacca globosa 7mm diametiens, seminibus complanatis suborbicularibus 2mm diametientibus in utroque loculo circiter 16.—*B. oblongifolio* Miers proximus differt insigniter calyce augescente *Athenaeam* simulante.

In silvis udis umbrosis ad Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Oct. 1903, *von Tuerckheim*, n. 8553 ex Pl. Guat. etc., quas ed. Donn. Sm.

Columnea calotricha Donn. Sm. (§STYGNANTHE Benth. et Hook.)—Undique pilosa. Folia leviter disparia oblongo-elliptica utrinque acuta subintegra. Pedunculi petiolis breviores. Calycis segmenta sejuncta spathulato-oblonga. Corolla subclavato-tubulosa calyce 3-plo longior. Disci glandula unica.

Fruticulus saprogenus e basi repente ascendens in exemplis suppetentibus 5–16^{cm} altus simplex caule petiolis foliis nascentibus floribus crinito-hirsutus, pilis articulatis rubro-tinctis. Folia subtus vinicoloria utrinque pilosa margine ciliata 5–8.5^{cm} longa 2–3^{cm} lata, petiolis 11–14^{mm} longis, internodiis 5–15^{mm} longis. Flores solitarii 40–42^{mm} longi, pedunculis 6–8^{mm} longis. Calycis segmenta subaequalia 13–15^{mm} longa obtusa. Corolla rubiginosa recta e basi gibbosa paullatim leviterque ampliata faucibus haud constricta ore subobliqua, lobis 4^{mm} longis inaequilatis. Bacca rubra ovalis 16^{mm} longa.—*C. moestae* Poepp. et Endl. proxima differt autem inter alias notas glandula disci solitaria.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Jul. 1903, *von Tuerckheim*, n. 8542 ex Pl. Guat. etc., quas ed. Donn. Sm.

Adenocalymna macrocarpum Donn. Sm. (§HANBURYOPHYTON Bur. et K. Sch.)—Glabrum. Folia conjugata, cirrho simplice vel plerumque deficiente, foliolis ellipticis vel oblongo-ellipticis apice subabrupte acuminatis basi acutis penninerviis subtus glandulari-punctulatis. Thyrsi densiflori, rhachide pedunculum altero tanto excedente. Corolla anguste infundibularis. Stamina medium corollae vix attingentia. Capsula linearis perelongata, seminibus latissime alatis, nucleo tenui.

Frutex scandens, caule verrucoso ceterum glabro. Foliola 7–11^{cm} longa 3.5–4.5^{cm} lata coriacea supra sicco saturate viridia subtus pallidiora pallidius marginata basi complicata, nervis lateralibus utrinque circiter 5, petiolis 12–16^{mm} longis, petiolulis 8–12^{mm} longis utrinque incrassatis supra canaliculatis. Thyrsi axillares et terminales bracteis foliaceis 1.5–2^{cm} longis suffulti glabri, pedunculo 3–4^{cm} longo, rhachide 6–8^{cm} longa, ramis primariis oppositis 1.5–2^{cm} longis erecto-patentibus dichasia gerentibus, bracteolis linearibus minutis, pedicellis 0.5–1^{cm} longis. Calyx eglandulosus pulverulentus campanulatus 6^{mm} altus mucrunculis denticulatus. Corolla flava pulverulenta 6–6.5^{cm} longa e tubo basilari cylindrico 7–8^{mm} longo subsensim ampliata ad 6^{mm} supra basin staminigera et ibidem pubescens, lobis inaequalibus 1–1.5^{cm} longis. Stamina majora 21^{mm} longa, minora 16^{mm} longa, staminodio 5^{mm} longo, antheris divaricatis nudis linearibus 3^{mm} longis. Discus pulvinatus 2^{mm} altus 3^{mm} latus. Ovarium lineare teres 6^{mm} longum puberulum, stylo 2.5^{cm} longo, stigmatis lobis lanceolatis

3^{mm} longis. Capsula generis adhuc longissima 29–52^{cm} longa 1.5^{cm} lata valde compressa eglandularis apice attenuata basi obtusa, valvis crasse coriaceis planis, nervo mediano percursis seminibus biseriatis pro loculo 20–25 alis hyalinis adjectis 4.5–5.5^{cm} latis 1.5^{cm} altis, nucleo 1^{cm} diametiente valde compresso.

Tecoluca, Depart. San Vincente, El Salvador, alt. 70^{m}, Jan. 1893, *Shannon*, n. 5055 ex Pl. Guat. etc., quas ed. Donn. Sm.—Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, ann. 1900, *von Tuerckheim*, n. 7759 ex Pl. Guat. etc., quas ed. Donn. Sm.—Eandem plantam in ditionibus Mexicanis collegit *Pringle* (n. 3898).—Haec exempla omnia sub *Cydista aequinoctiali* Miers, var. (*Bignonia sarmentosa* Bertol.), olim distributa sunt.

Cornutia cymosa Donn. Sm.—Ramuli teretes. Folia ampla ovalia vel suborbicularia utrinque rotundata. Cyma dichotoma corymbiformis latissima. Drupa generis adhuc maxima depresso-globosa, putamine osseo profunde exsculptato lacuna basali bifido.

Arbor, coma rotunda (*Tonduz* in schedula), ramulis petiolis cymae axibus pubescentibus vel glabrescentibus, gemmis ferrugineo-pilosis. Folia 14–27^{cm} longa 13–20^{cm} lata utrinque minute strigillosa siccitate bullata, costa nervisque validis, his utrinsecus 7–10 patulis sub margine junctis, venis transversis parallelis, venulis minute reticulatis, petiolis 2.5–4^{cm} longis. Pedunculus 3–10^{cm} longus, cyma sexies–decies dichotoma 10–14^{cm} alta 16–23^{cm} lata laxe floribunda, axibus robustis subangulatis, pedicellis 2–5^{mm} longis. Calyx fructifer pubescens planiusculus 6–7^{mm} latus, lobis ovatis. Drupa transversim leviter compressa 8–12^{mm} longa 10–15^{mm} lata, putamine sulcato et foveato a basi usque ad medium versus excavato abortu biloculari, seminibus lineari-oblongis. Flores ignoti.

In pascuis ad La Palma, Prov. San José, Costa Rica, alt. 1460^{m}, Sept. 1898, *Tonduz*, n. 7383 ex Pl. Guat. etc., quas ed. Donn. Sm. (n. 12555 herb. nat. Cost.).

Trophis macrostachya Donn. Sm.—Folia maxima oblongo-elliptica longe tenuiterque caudato-acuminata basi rotunda vel acuta supra medium repando-denticulata vel subintegra. Spicae masculinae dichotomae, femininae longissimae, perianthio fructifero sessili vel breviter pedicellato.

Arbor, ramulis novellis cum petiolis stipulis spicis pubescentibus. Folia coriacea supra glabra subtus nervis venisque pubescentia 15–22^{cm} longa 6–9^{cm} lata, acumine caudiformi 2–3^{cm} longo, nervis lateralibus utrinsecus 12–14 juxta marginem junctis, petiolis 1–2^{cm} longis, stipulis ovato-lanceolatis convolutis 5–6^{mm} longis. Spicae masculinae bis furcatae continuatim densiflorae 5.5^{cm} longae, perianthii segmentis imbricatis 2^{mm} longis bracteolas et stamina aequantibus. Spicae femininae plerumque binae, floriferae 4–6^{cm} longae, fructiferae 10–13^{cm} longae, bracteolis rotundis 0.5^{mm} longis ciliatis, perianthiis floriferis compactis, fructiferis laevibus pubescentibus ovalibus vel ovoideis 8–10^{mm} longis, pedicellis interdum 1–3^{mm} longis raro ramosis, fructu apice ipso tantum libero, semine 6^{mm} longo.

In pascuis ad Las Vueltas, C. R., Nov. 1898, *Tonduz*, n. 8124 ex Pl. Guat. etc., quas ed. Donn. Sm. (n. 12802 herb. nat. Cost.).—In silvis ad Palmar, Costa Rica, Mart. 1892, *Tonduz* (n. 6751).—Tuís prope Turrialba, Prov. Cartago, Costa Rica, alt. 620^{m}, Jul. 1897, *Pittier* (n. 11266).—In silvis ad Tuís, Prov. Cartago, C. R., alt. 650^{m}, Oct. 1897, *Tonduz* (n. 11357).

Sahagunia urophylla Donn. Sm.—Praeter perianthium glabra. Folia integra oblongo-elliptica vel late ovalia caudato-acuminata basi acutiuscula vel rotunda, nervis lateralibus utrinsecus 6–8. Pedunculi feminini solitarii aut gemini. Perianthium fructui pendulo infra apicem adnatum, pericarpio cartilagineo.

Folia subcoriacea supra saltem in sicco obscura subtus viridia, nunc 13–20^{cm} longa in medio 5.5–8.5^{cm} lata basi subacuta, nunc 6–8^{cm} longa 4–5^{cm} lata basi rotunda, nervis venisque utrinque praesertim subtus manifestis, venulis grosse reticulatis, petiolis 1–1.5^{cm} longis, stipulis lanceolatis 2–3^{mm} longis caducis. Pedunculi feminini 3–4^{mm} longi, fructibus 2–4 capitatis, additis floribus nascentibus nonnullis. Perianthium crasso-carnosum fusco-velutinum ovale 12^{mm} longum collo subintegro apiculatum, fructu subgloboso 6–7^{mm} diametiente, stylo 3^{mm} longo, semine infra apicem affixo rufescente scrobiculoso. Flores utriusque sexus deficiunt.—Haec species generis tertia adhuc edita ab *S. Mexicana* Liebm. glabritie et foliis pro rata latioribus caudatis paucinerviis, ab *S. strepitante* Fr. Allem. foliis integris pedunculis saepe binis fructibus minoribus inter alia differt.

In silvis prope Puerto Sierra, Honduras, Jan. 1903, *Percy Wilson* (n. 54).

Coussapoa oligocephala Donn. Sm.—Folia oblongo- vel subovato-elliptica apice obtusiuscula et apiculata basi rotundata et emarginata discoloria supra glabra subtus arachnoidea. Cyma brevissime bis terve dichotoma, capitulis paucis subglabris. Stamen perianthio lobulato bis longius, anthera quadriloculari.

Frutex epiphyticus (fide oculatissimi repertoris supra *Achras Sapota* L. re vera parasiticus), ramulis novellis stipulis petiolis pedunculis cum cyma pilosis. Folia 10–16^{cm} longa 4–7^{cm} lata, nervis lateralibus utrinsecus 9–11 rectis in margine ipso terminatis, imis e basi extrorsum ramosis, petiolis 1.5–2.5^{cm} longis. Pedunculi masculini solitarii vel gemini 2–2.5^{cm} longi, capitulis 3–5 circa 4^{mm} diametientibus, bracteolis tenuissime spatulatis. Perianthium turbinatum vix 1^{mm} longum, lobulis brevibus rotundis incrassatis uti bracteolarum apex ad lentem puberulo-punctulatis. Capitula feminina non vidi.

Cubilquitz, Depart. Alta Verapaz, Guat., alt. 350^{m}, Apr. 1904, *von Tuerckheim*, n. 8659 ex Pl. Guat. etc., quas ed. Donn. Sm.

BALTIMORE.

THE DEVELOPMENT OF ROOT HAIRS.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXXIV.

LAETITIA MORRIS SNOW.

(WITH PLATE I AND SIX FIGURES)

INTRODUCTION.

EXPERIMENTATION upon the effect of external agents on the development of root hairs is complicated by the fact that when external conditions are varied the internal factors are disturbed by an unknown amount. The varying of only one condition, which is the essential feature in accurate research, was thus extremely difficult, if not impossible. Therefore, the results to be set forth here are understood to be tentative. The last experimental work upon the immediate subject is that of SCHWARZ (**75**), to which the reader is referred for most of the earlier literature. Apart from three or four papers, the references to the causes for the development of root hairs are found incorporated, here and there, in reports on root studies, and as a rule are merely casual observations. The work here reported has been an endeavor to add some facts and suggestions as to the causes for the production of root hairs, variations in their structure not being considered.

LIGHT AND DARKNESS.

In view of the fact that in darkness there is generally an increase in the length of the axial organs and of their component cells (**47,** p. 64; **37,** p. 254), and because authors differ as to the effect of light and darkness upon the development of root hairs, it seemed best to reinvestigate the matter. SCHWARZ (**75,** p. 163) reports no effect; WENT'S (**85,** p. 8) experiments were not very convincing one way or another; DEVAUX (**10,** p. 306) finds that light retards growth and favors the development of root hairs; PETHYBRIDGE (**63a,** p. 235) reports that light retards the production of hairs upon the roots of oats and wheat growing in water cultures. The last experiment was repeated several times, but very little difference was noted

between the jars, the roots showing individual peculiarities of growth under both conditions. In one experiment the general growth in length seemed to be a little less in light, accompanied by a slight increase in the length and thickness of the hairs. In others no difference was noticed. No zonal arrangement was observed, as was mentioned by DEVAUX (**11**). According to MACDOUGAL (**47,** p. 246) the development of hair upon aerial organs in response to light conditions varies greatly, some plants having a tendency to decreased hair production in darkness, and others showing no change.[1]

A. Seedlings.

Preliminary experiments showed that the primary roots of seedlings of *Triticum vulgare, Zea Mais, Pisum sativum, Cucurbita Pepo, Vicia sativa, Helianthus annuus, Brassica alba,* and *Raphanus sativus* produced hairs, for a longer or shorter zone, in air or water regardless of the light conditions. This is attributed by SCHWARZ (**75,** p. 162) to the abundant food supply, seedlings being in a measure independent of external conditions for their existence.

Seeds of wheat, corn, pea, and squash were sprouted upon moist filter paper under illuminated and darkened bell-jars. On plants of the same age the hair zones were measured. No decided difference was found, though the hair zones averaged somewhat longer in darkness. The influence of the light was not strong and was probably indirect, through its effect upon growth.

An attempt was next made to compare the increase of surface per square millimeter under the two conditions. Seedlings of sunflower, white mustard, and radish were attached to pine bars by means of filter paper and rubber bands, as described by NEWCOMBE (**55,** p. 150), and placed in glass jars, one set being illuminated and the other darkened. The measurements were taken in all cases, as nearly as possible in the zone of best average development, near the top of the root. The closeness of the hairs varied in different parts of the root, but the average of the numerous counts was probably not far from fair. The increase (in square millimeters) per square

[1] In connection with the experiments here reported, the condition of the hairs on the epicotyl of etiolated and normal seedlings of Helianthus were compared. In the former case the cells were longer and the hairs were not only thus farther separated, but fewer cells produced hairs.

millimeter was calculated by multiplying the average length by the average width by the average number of hairs per square millimeter by π. Scrutiny of the results in the sunflower shows that for equally long roots the increase of surface varies, but that there is a slight predominance in the average increase of plants in dark (14.8) over those in light (14.02), and that this is entirely due to the greater average number of hairs per square millimeter (395 as against 373). The individual measurements for white mustard and radish show a like fluctuation of increase, but this time with a predominance in the average of light over darkness.[2] This is probably due to the fact that these are small seeds with little reserve food, and soon begin photosynthetic work in the light, while the plants in darkness have no such advantage. No evident difference in the length of hairs was observed in dark and light, as was noted by BENECKE (**5**, pp. 28, 29) for rhizoids of Lunularia.

B. Older roots.

Under ordinary conditions corn plants one or two weeks old, with roots growing through the bottom of the pots, did not produce hairs in water, whether illuminated or not. DEVAUX (**10**), on the other hand, found that light favored hair development on the roots of corn two months old growing in water. These plants, however, had been subjected to the rather severe operation of having all the roots cut off to one centimeter from the base, after which they were plunged into water. Upon repeating the experiment it was found that the plants in a day or so became yellow and unhealthy. In light five apparently healthy adventitious roots developed, and produced several isolated patches of hair, usually at the same time on all the roots, generally covered with a film of bacteria. In the darkened jar only three apparently healthy roots and two diseased ones were developed. No hairs or bacteria films appeared, although the odor of the culture betrayed greater decomposition than in the illuminated jar. Too many factors are involved to make the experiment, in its present form at least, of much value.

[2] Thus, mustard showed average increase, dark 41.33, light 44.11; and the radish, dark 29.44, light 32.09. Here also number of hairs, 321 to 344 and 345 to 357, accounts for the increase.

WENT (**85,** p, 8) found in aerial roots that light was not favorable to hair production except in very damp air, which makes it appear that with aerial roots in general moisture is of much more importance for hair development than light (PFEFFER **64,** p. 130).[3]

When seedlings of corn were allowed to send their roots through the bottom of the pots into moist chambers, one darkened and one left in diffuse daylight, little difference was observed between them, some roots in light producing more hairs and some less than those in darkness. There seemed a slight tendency for the hair to be thicker in light. MER (**51,** p. 584) found variation in the appearance of hairs on the different roots in the same culture, and considers "cette inégalité d'apparition des poils dans un même milieu est bien propre à montrer que leur développement est étroitement lié à la constitution particulière de chaque radicelle." No zonation such as DEVAUX (**11**) reports was noted in these cultures. In some cases, wheat, corn, and sunflower produced hairs in irregular zones, which however could not be traced to the effect of light and darkness. Any one of the many causes which may result in irregular growth might have been responsible. Where there is any effect on the development of root hairs produced by light, it appears from the above consideration to be due to the indirect effect upon growth. It does not appear to have the direct retarding influence as found by VÖCHTING in the case of the growth of willows and the development of new organs (**83,** pp. 152–162).

TEMPERATURE.

The effect of high and low temperatures upon growth has been studied by many investigators (**64,** pt. 2), with the general result that increase of temperature favors growth on account of greater or more rapid absorption. KIRCHNER (**29,** pp. 353–355) reports growth increased by high temperatures; NĚMEC (**54a**) found longer, thinner cells in warm water than in cold; POPOVICI (**67,** pp. 37, 88) states that high temperatures (33° C.) diminish the zone of elongation, while low temperatures, just above the germination minimum, increase it, although the total growth is less. KOSAROFF (**32a**)

[3] For numerous instances of hair production on aerial roots touching a support, see the bibliography in WENT's paper.

GREELEY, COLORADO

and KRABBE (**33**, p. 474) found roots to absorb less water at low temperatures. VAN RYSSELBERGHE (**70a**) considers that merely the rate of absorption is affected by the impermeability of the protoplasm. DEVAUX (**11**, p. 52) considers temperature to be of great importance in the production of root hairs, but has as yet merely made that preliminary statement. SCHWARZ (**75**, p. 158) reports that optimum temperatures (27–28° C.) do not overcome the inhibitory effect of water, as the roots grow smooth.

A comparison of the increase of surface in the cases of mustard and radish shows that temperature variations of small amount have no appreciable effect. The effect of greater changes was tested with seedlings of wheat and corn. These were placed in water at temperatures of 33–38° C. No hairs appeared on the parts in water, while the parts in air, as the height of the water varied a little, produced a few hairs.

Wheat seedlings in warm water, in water at room temperature, and in cold water, grew in all three conditions, and gave the following results:

Condition	Temperature	Duration	Result
Cold.....	4.5–15.5° av. 11.6° (once 22.5)	Dec. 8–18	Haired to the tip, long and close set
Medium.....	16.0–29.5° av. 23.7°	Dec. 8–21	Hairs not so good, long bare spaces at tip
Warm.....	27.0–48.0° av. 34.5°	Dec. 8–14	Only two lived, smooth

Corn seedlings at temperatures of 29–37° (av. 33.4°) produced no hairs; while control plants at 16–27° (av. 22.9°) were haired at first, but later the root assumed its usual water type. This experiment was repeated many times with various modifications, and gave the same results.

That the smooth condition was due to the growth, rather than to the direct action of the heat upon the epidermal cells, was suggested by the following experiment. Corn seedlings were fastened in tap water of temperature 18–20° C., which was kept flowing in a very small stream from a rubber tube reaching the bottom of the jar. Under these conditions all the roots grew smooth and straight, omitting the seedling zone of hairs. Whether this was from the constant

supply of oxygen or on account of rheotropic stimulation by the rising water currents was not evident (*fig. 10*). The experiment was continued by varying the temperatures in the cold jar from 4–26°, giving very short hairs on one healthy root and on portions infested with bacteria. Once or twice a tuft of hairs was produced when seedlings were changed from cold to warm water, due possibly to retardation (ASKENASY **2,** p. 70; TRUE **80,** p. 400), but more probably to the more rapid adjustment and stretching of the epidermal cells in the warm water than of the inner cells. KIRCHNER (**29,** p. 353) found that 4° C. allowed of little or no growth of corn roots, while wheat elongated at 0°C., which may partially account for the different hair conditions in the two plants in cold water.

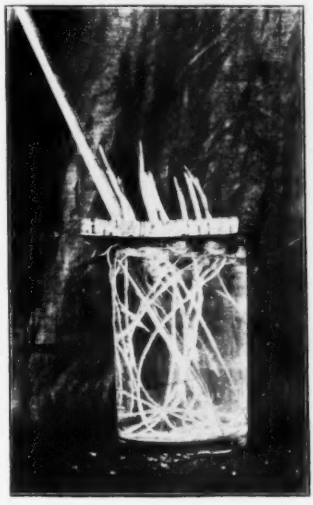


FIG. 10.—Corn roots growing in flowing tap water.

Wheat was planted in a pot of garden soil, and the roots allowed to come through the bottom and pass into warm water, of temperatures varying from 27–33° C. The roots were smooth at 33°, had scanty and irregular hairs at about 30°, and were more or less hairy at 27°. As this was tried repeatedly with the same result, it seems that for wheat, under these conditions, 30° C. is about the limit of hair production.

During a period of high temperature in the room, Elodea roots growing in soil were observed to be straight and smooth instead of kinky and hairy as is usual. When the temperature fell to the normal point, about 21° C., the roots assumed their usual aspect. In one case measured, the root growing in ground quartz at 27–34° C. elongated 4^{mm} in five days, and was curved and piliferous. The heat was not able under these conditions to suppress hair development. Another plant of Elodea growing in a glass cylinder had accumulated a little organic matter in the bottom of the vessel, not

enough to make a layer, and consequently not enough to offer any appreciable resistance to root growth. The roots growing along the bottom in this debris curled and developed hair in some places, but were smooth where they curved up into the water.

CONTACT.

Concerning the effect of contact upon the production of root hairs authors differ. SCHWARZ (**75,** p. 160) offers no explanation for their production in the case of water roots of Nuphar or Elodea entering the substratum, but thinks they are not due to contact, chemical stimulation, or retardation of the growth of the root. On air roots of aroids and orchids dry contact produced no hairs, nor was he able to cause them on Elodea (presumably in water) by contact with glass beads or ground glass. In air roots he speaks (p. 120) of the suppression of hair by too close contact. EWART (**14,** p. 237) makes the statement that "for the formation of root hairs on the root tendrils (of Vanila) moisture is essential, darkness and contact accelerating, and light and dryness retarding it." PFEFFER (**64,** p. 156) denies the effect of contact, attributing the hair development to greater moisture near the support. WENT (**85,** p. 8) also thinks that not contact but moisture and absence of light are the factors.

In the experiments here reported there was a production of hairs on the roots of Elodea not only when the root grew into the mud at the bottom of the aquarium, but also when ground quartz was substituted for the mud, while in every case roots growing freely in the water produced no hairs. Several of these straight, smooth roots were allowed to grow into ground quartz, and the tips were found usually much bent and curved, and in all cases covered with hairs. Sections were made from roots in water, soil, and quartz, and the cells were measured. The averages were:

MEDIUM	AV. LENGTH IN MM. OF CELLS		CONDITION
	Of epidermis	Of cortex	
Water	0.104	0.160	Smooth
Quartz	0.091	0.110	Hairy
Soil	0.068	0.100	Longer hairs

There seems, therefore, to be a decided shortening of the cells in the substratum. As the mud at the bottom of the aquarium was of closer texture than the quartz, it probably offered greater resistance to the growth of the root. If the statement made by HABERLANDT (**22,** p. 188) concerning Elodea—"denen die Wurzelhaare in Wasser vollkommen fehlen, während sie beim Eindringen der Wurzeln in Erde sich reichlich einstellen"—means that the resistance of the substratum is instrumental in bringing about the production of root hairs, these results agree. The possibility of the chemical stimulus of the soil has been mentioned.

It does not seem probable that surface contact is a factor in the production of root hairs in soil, for when the earth is saturated the hairs on corn seedlings disappear, and those on wheat seedlings are decreased, although the soil particles are still there. This was stated by SCHWARZ (**75,** p. 160). In order to test the effect of contact with a smooth, solid body upon the epidermal cells of the root, corn seedlings were grown with their roots between glass plates, and in glass tubes open at the end. Where the roots filled the diameter of the tubes or the space between the plates, hairs were absent, both in air and water. On the sides not touching the plates hairs appeared nearly to the tip in air, and in the upper portions in water, as they do under ordinary conditions. Thus the contact on two sides of the root has no apparent effect on the hair production on the other two sides. Where the root did not fill the tube, hairs appeared in the usual zone in water and bent against the glass.

RETARDATION OF GROWTH.

It is of importance when speaking of the effect of growth upon the production of root hairs to indicate the effective stage. When the statement is made that slowing the growth of a root favors the production of root hairs (**51, 52, 11**), the retardation may be due either to fewer cell-divisions or to less elongation of the cells.

A. Rate of growth in air and water.

According to MER (**51, 52, 53,** p. 1279), retardation of the growth of a root produces or increases hair development. Thus lentil roots (**52,** pp. 665–6), growing straight and smooth in air, became piliferous when their growth was checked by the earth. Also, when

these roots and those of corn were papillate in air, passage into water checked their growth, caused curves, and made the hair longer at first, after which the roots grew smooth. Swellings and curves are generally covered with long hair, for which he offers the following explanation:

> Lorsque les substances plastiques ne sont pas entièrement utilisées par l'extrémité végétative, ainsi que cela arrive quand l'accroissement de cette dernière est entravé par une cause quelconque, elles se portent sur les éléments voisins et principalement sur les cellules épidermiques dont les parois libres peuvent se développer plus facilement. De là des renflements, des radicelles et des poils.

SCHWARZ (**75,** p. 149) does not consider MER'S results trustworthy, and thinks that the checking of growth cannot cause development of hairs; but on the other hand that hair production goes with optimum growth energy (p. 155). MER repeated his experiments with the same results (**51**). SACHS (**71,** p. 410) found that the growth of roots in water is more rapid than in air. SCHWARZ (**75,** p. 154) reports slower growth in water than in air or earth, with a consequent decrease of hairs. Rapidity of growth caused by optimum temperature, however, was not able to overcome the inhibitory effect of water (p. 155). The following quotation is not quite in harmony with his criticism of the explanation offered by MER: "Am längsten werden die Wurzelhaare im feuchten Raume, und wenn das Wachsthum der Wurzel durch Nutation u. s. w. besondere Hemmung erleidet."

JAR 1.

24-HR PERIODS	GROWTH IN 24 HRS. (mm.)		GROWTH PER HR. (mm.)		Temp.	CONDITION
	Water	Air	Water	Air		
I	32.0	..	1.33	....	..	
II	....	21	....	0.88	..	
III	14.0	..	0.58	....	12°	Hairs half way down
IV	....	5	....	0.20	11	One tuft
V	4.5	..	0.19	....	14	No hairs
VI	....	7	....	0.29	19	Hairs back to one tuft
VII	6.0	..	0.25	....	18	Doubtful hairs at top
VIII	15.0	..	0.65	....	18	Evident hairs at top
IX	30.0	..	1.25	....	12	No hairs
Average	16.9	11	0.71	0.46	..	

JAR 2.

24-HR. PERIODS	GROWTH IN 24 HRS. (mm.)		GROWTH PER HR. (mm.)		Temp.	CONDITION
	Water	Air	Water	Air		
I.....	15	..	0.63	....	12°	Few towards top
II.....	....	6	....	0.25	11	No hairs
III.....	7	..	0.20	....	14	No hairs
IV.....	....	10	....	0.42	19	Hairs back to last air period
V.....	15	..	0.63	....	18	No hairs
VI[4].....	5	10	0.84	0.42	18	Abundant in air, none in water
VII.....	15	..	0.54	....	12	Little evidence at top
VIII[5].....	....	10	....	0.42	18	Abundant
IX[5].....	....	6	....	0.25	12	Good hairs
Average.....	12.5	8.4	0.52	0.35	..	

An attempt was made to ascertain whether the difference in rate of growth of corn seedlings in air and water could be the cause for the lack of root hairs in the latter medium. The seeds were planted in small pots in a mixture of sand and humus, or in garden soil, and the roots allowed to pass through the bottom of the pots. By placing the pots in the tops of wide-mouthed bottles half full of water, the roots hung in moist air, and by changing the level of the water, alternating conditions of air and water were brought about. The roots were allowed to remain in each medium for twenty-four hours.

It will be seen upon examination of the above tables that there was a general tendency to produce hairs in air and to cease their development in water. The effect of the air was not lost immediately, but in some cases the hairs extended a short distance into the water. I see no satisfactory explanation for the non-appearance of hairs in the first air measurement in *jar 2*. Lack of energy from low temperature appears to be the most simple explanation. The short growth in the following water period was still in the elongation phase when placed in air, and hairs are developed by differential elongation. Other experiments not recorded here gave the same general results.

[4] Grew into water and the different rates could not be calculated; so that as two air periods of 10mm growth had a rate of 0.42mm per hr., that was assumed for this calculation.

[5] Measurements of a root at the top of the jar.

Medium	Av. growth per day in mm.	Av. growth per hour in mm.	Av. length of cells in mm.	Approximate no. of cells per day
Air.....	8.6	0.36	0.067	128
Water.....	11.2	0.45	0.085	132

The lengths of the cells are averages from measurements of air and water roots twenty-four hours old, having the same length as the average growth per day in the respective medium. We find that the rough approximation of the number of cells formed per day gives about the same result for the two media; consequently the difference in length of the roots and in the rate of growth is due to the greater stretching of the cells in the case of the water roots.

B. Retardation by mechanical means.

Concerning the effect of retarding growth by mechanical means, SCHWARZ (**75,** p. 159) thinks it is impossible to produce hairs in this manner. He was not able to cause them to develop by stopping the growth of the root by wire gratings, nor in general by narrow tubes. The fact that the wire might have had a toxic effect would discredit the former method of experimentation. He does not consider the resistance of the earth to be a cause for hair production (p. 160), but states that it results in developing hairs nearer the tip. While this may not be due to a greater number of cells producing hairs, it at least indicates the favoring effect of resistance, in that hairs elongate in a region which otherwise only shows the papillae.

A pot of corn was placed in the top of a glass cylinder, with the roots passing through the bottom and entering the water. One root grew horizontally and struck the side of the vessel, becoming kinked and hairy. On May 9 it was drawn away from the glass, and on the next day showed a smooth space. On May 12 the root again reached the glass, and on May 15 showed hairs. The jar was darkened and a glass rod was placed under a smooth vertical root, as in diagram, *fig. 11*. On May 14 the root showed hairs, but had swung free and was growing smooth. A plaster cap was unsuccessful, as it killed the tip of the root. With the death of the tip many laterals grew out producing hairs, some touching the glass and bending, and some becoming kinky in free water.

A second cylinder was set up as in *fig. 11*. The glass rod was

placed under a smooth straight root, but in twenty-four hours the root had curved and grown past the surface, a tuft of hairs on the curve indicating that some retardation of growth took place. For over a week the curling and hair production continued, then the root grew horizontally and struck the glass side. It became kinky and hairs continued to be formed for five days.

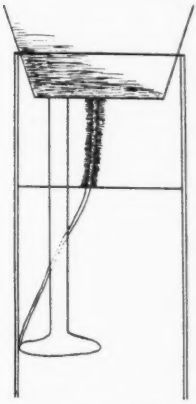


FIG. 11.—Diagram of apparatus to stop the growth of a root by a glass rod.

The fact that kinking takes place in free water shows that some other factor or factors besides resistance must be acting, but the facts brought out in the two experiments make it appear possible that resistance may be a partial cause for the kinking and hairiness of roots.

As the plaster cup in the preceding experiment was unsuccessful, glass tubes were tried. They were of sufficiently small bore to prevent a relief of pressure by too great bending. Smooth roots of corn were repeatedly allowed to grow into glass tubes (*fig. 12*). Usually the tip became more or less swollen, nearly or quite filling the tube. Primary roots showed kinking at the bottom, and hairs appeared in diminishing lengths from the bottom to the top. Only a few hairs appeared on the adventitious roots. When kept at high temperatures (24–34°C) the roots grew smooth, although bent and curved. If the resistance were relieved by allowing the roots to curve above the tube, hairs ceased to appear, conforming with the statement of MER (**51**, p. 584) that feeble retardation is not able to produce hairs. In one experiment the growth appeared to be so great that the roots were crushed and broken, producing no hairs on these portions.

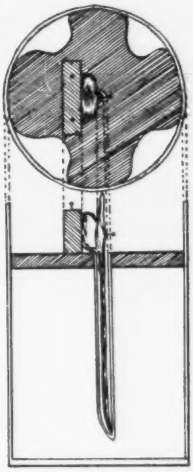


FIG. 12.—Diagram of apparatus to stop the growth of a root by a glass tube.

C. *Wounding.*

SCHWARZ (**75,** p. 158) was not able to cause hair formation by cutting off the roots 2–10^{mm} from the tip, nor by burning the tip with caustic. In my experiments the results were various according to the conditions. If the wound were not of sufficient depth to retard growth, if it were beyond the elongating zone, or if the plants were grown in warm water, no swelling or hairs appeared; otherwise hairs were produced. Thus in corn seedlings the tips of primary roots were pinched off about 1^{mm} from the tip. One showed hairs upon the swollen tips; another sent out a tuft of hairs and then grew smooth. In the latter case the wound was not of sufficient depth to more than slightly retard the growth. Of roots cut and burned, several showed hairs, the burned ones curving; several simply stopped growing and produced laterals; while others showed no effect. The cut tips of corn roots growing in air and producing short hairs became slightly swollen in twenty-four hours, and long hairs appeared above the cut. Both in light and darkness hairs were produced above the cut, whether the swelling appeared or not. This may have been due to the appearance of new hairs among the old ones, or to the stimulated growth of some of the old hairs, but more probably to the retardation of the zone in process of formation when the operation was performed. DEVAUX (**10,** p. 308) states that new hairs may appear among the old ones, but appearances which might be interpreted in that manner might be due to arrested development of some of the hairs. This would be difficult to decide, unless hairs were actually seen to originate between others (*fig. 2*). SCHWARZ (**75,** p. 165) and HABERLANDT (**75,** p. 187) state that hairs are always produced in acropetal succession.

D. *Medium.*

SACHS (**71,** p. 410) found that roots of land plants grew more rapidly in soil than in air or water, and his results have been confirmed by WACKER (**84,** pp. 109–115). The latter, however, found that in slimy soil the growth was retarded more than in water, and the denser the material the slower the growth. PFEFFER (**66,** p. 320) says the rate of growth is not affected by the density of the medium, roots growing as rapidly in fluid clay as in water. These conflicting

results are due probably to the different amounts of water in the soils used.

Roots of corn grown in ground quartz, garden soil, and air gave these results: in quartz, av. length 19.5^{mm}, hairs abundant; in soil, 22.3^{mm}, hairs good; in air, 50^{mm}, hairs poor. From these figures it seems that the resistance of the substratum bears direct relation to hair production; but the factor of water supply has undoubtedly an important influence, the quartz being less compact and therefore drier than the garden soil. Other experiments showed slower growth in air and quartz than in soil or water.

The behavior of roots of Elodea in the substratum has been mentioned, with the suggestion that retardation due to the soil particles was the principal factor. It will be shown later that a diminution of oxygen supply has a tendency to suppress hair production. There is less oxygen in the substratum than in the freely flowing water above it. It appears, therefore, that retardation, whether from soil resistance or chemical influence, must be the chief factor in producing the kinking and the hairs. Whether the hairs are due to the kinking, or both are due to the retardation of growth, cannot be stated. The production of hairs by retarding growth with glass tubes took place at times without kinking, though in the majority of cases the two results were associated. SCHWARZ (**75**, p. 159) considers "nutation" (kinking) the most potent factor in the production of root hairs, but it seems as if they might both be referred to unequal retardation of the growth of the root. Measurements of the epidermal cells of roots of Elodea give the following averages in millimeters:

Medium	Smooth	Haired
Water	0.104	.....
Quartz	0.110	0.077
Soil	0.128	0.065

Here the soil roots show better hairs than the quartz, and have the shortest cells when hairy. As will be seen later, however, the comparative lengths of cells of different roots can only be taken as supporting not as decisive evidence.

Corn seedlings were allowed to send their roots between glass

plates, on one of which was a layer of paraffin with sections covered with dune sand and ground quartz. The growth over the paraffin was smooth; the roots running over the sand were wavy, in some places producing hairs; and the one on the quartz kinked with more hairs (*fig. 13*). One root from the plant growing over quartz

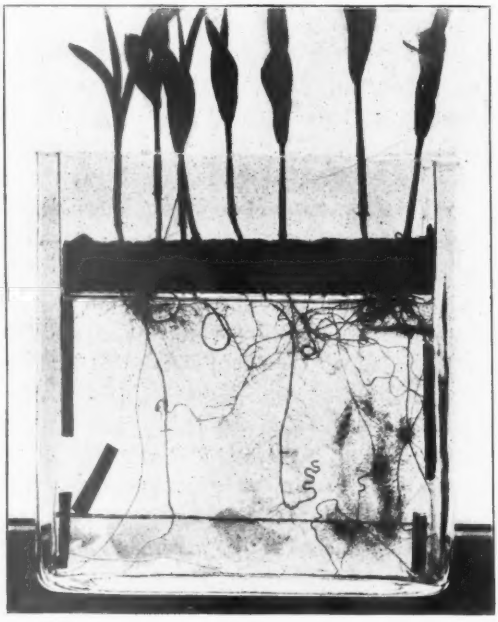


FIG. 13.—Corn seedlings growing in water in a glass jar between paraffined glass plates, on which was spread in the center a layer of coarse ground quartz; on the right is dune sand; on the left is clean paraffin.

wandered into the paraffin section, curled, and developed hairs. This appeared at the same time as the curling of the main root and may have been correlated with it. A second experiment with the sections horizontal also showed the laterals wavy at the same time that the main root kinked on the quartz.

WATER CONTENT.

According to several investigators (WIESNER **88**, p. 149; PFEFFER **64**, p. 100; PALLADIN **59**, p. 371; BRENNER **7**, p. 435; MACDOUGAL

47, p. 64; *et al.*) the attenuation of the axial members of etiolated plants, where it occurs, is due, in part at least, to a lack or diminution of transpiration. A greater proportion of water in etiolated plants is reported by MACDOUGAL (**47,** p. 64), PALLADIN (**60a**), JUMELLE (**28,** p. 386), *et al.*

Whether turgor is the cause or the result of growth, elongation of a cell is directly connected with its turgescence, greater water content producing greater elongation. Besides instances of etiolation, this is shown by the curling of roots which rest on the surface of water (SACHS **71,** pp. 398–9); by the rounding up of filamentous algae (LIVINGSTON **43,** p. 308; **44,** pp. 310–312) and of fungi (RACIBORSKI **68,** p. 111) upon withdrawal of water by osmotic solutions, and by the tendency of cells to stretch radially from loss of water by transpiration (KOHL **31a,** p. 297). The more turgid a cell becomes, therefore, the greater the tendency to stretch in a longitudinal direction. The water content of the root cells may be affected by changing the moisture content of the air, by altering the water content of the soil, or by surrounding them with solutions of higher osmotic pressure.

A. Transpiration.

It is well known that aerial transpiration favors the production of hairs upon aerial organs, WOLLNY (**89,** pp. 418–435) reporting an increased number of piliferous cells by count. On the other hand, some hairy-leaved plants grown in an aquatic habitat become smooth (COSTANTIN **8,** p. 40), and many have noted the absence of hairs on roots in water. Experiments to determine the effect of transpiration from leaves upon the development of root hairs gave negative results. Roots grown in saturated air at various temperatures showed few or no hairs, and any change that reduced the moisture content favored their development. Control plants showed that the temperatures used could not alone produce the results.

B. Saturated soil.

For these experiments corn and wheat were chosen because the former is very sensitive to the inhibitory effect of water, and wheat readily develops hair in that medium.

Corn roots grown in garden soil kept moist were found well covered with hair after seven days. Other pots were submerged in water for eight days. The uninjured primary roots showed long bare spaces and the laterals were nearly or entirely bare. One plant was allowed to dry out and the roots again became haired.

Wheat was grown in garden soil in pots, one of which was placed in water and the other watered a little every day. After a week's growth, the plants were found to have abundant hair on the roots passing through the pots into water, only zones of papillae on the roots in saturated soil, but good hairs on those in the dry pot. The zones may correspond to the drier conditions when the water fell below the bottom of the pot. In a control experiment precautions were taken to obviate the possible effects of a lack of mineral salts in the water on account of the absorptive action of the soil particles. It seems therefore that something besides lack of nutrient salts (probably lack of oxygen) must in this case be the important factor.

C. Osmotic solutions.

In connection with the experiments with osmotic solutions, cleaned sand was saturated with solutions of lactose, saccharose, and glucose of a concentration which allowed the zone of hairs to form. In lactose and glucose the hairs were much reduced and their presence in saccharose was extremely doubtful.

The effect of solutions upon the growth of plants and plant organs has been extensively investigated, but many of the results reported are of little use on account of a failure on the part of the investigators to distinguish the physical effect due to the osmotic action of the solution, and the chemical effect of the ions (LIVINGSTON **44,** pp. 124–7). Many authors (NOLL **57a,** GERNECK **18,** *et al.*) think the characteristics of water roots to be due to the lack of nitrates in the culture. The results of GERNECK and KRASSNOW (**36a**), showing that roots were richly haired in $CaNO_3$ solution, while the usual number of hairs or less were developed in KNO_3 solutions, make it appear that the kation has some special effect, and the mere absence of nitrates may not be the only factor to be considered in connection with the form and structure of water roots. Mere speculation on the subject, however, is of little value; careful physical

and chemical experimentation is necessary. SCHWARZ (**75,** pp. 156–7) reports a cessation of hair production in "concentrated" solutions (15 per cent. $CaCl_2$ and KNO_3 and 10 per cent. nutrient salts), but no distinction is made between the physical and chemical effects of the solutions. PETHYBRIDGE (**63a,** p. 235) found root hairs more or less variable in his cultures of inorganic salts.

The results of my experiments are too incomplete and inconclusive to warrant detailed publication. Many of the plants died, and often an experiment when repeated did not give exactly the same result as before. Some factor or factors seem to have escaped observation. A possible variable factor is suggested by the variable results obtained by BENECKE (**5,** p. 24) with Lunularia buds, when he used different kinds of glass for the vessels. Considering such sources of error my results could only be considered as suggestions for further investigation.

Among non-electrolytes, lactose, saccharose, glucose, glycerin, and mannite were used, in normal solutions (1 gram-molecule to 1 liter of water). Dilutions were made from this, sometimes with tap water boiled and cooled in the air and shaken to renew the oxygen content, sometimes with unboiled tap water, sometimes with distilled water, and sometimes with distilled water redistilled from glass. The most convenient method of experimentation proved to be to nearly fill stender dishes with the solutions and to float upon the surface of the liquid round cakes of paraffin about one-quarter of an inch thick with funnel-shaped holes in which the seeds were firmly wedged. This method avoids pins and the cakes in a measure protect the solution from bacteria. They were easily kept clean and could be remelted for each experiment.

In ten experiments with lactose (nine with sunflower and one with corn) five showed variable limits (0.2–0.4 N) for hair growth. In 0.5 N solution very little growth of the roots took place, and only once were papillae found under the microscope. The seedling zone of hairs grew best in water and diminished with increasing concentration.

In five experiments with saccharose two sunflowers gave 0.5 N, one 0.4 N, and one 0.2 N (with boiled tap water) as the limit for hairs; but the growth was not good. Allowing sunflower roots to

grow through pots into water and solutions made with tap water, the 0.5 N solution produced the best hairs. Corn roots growing through pots into water and solutions made with redistilled water showed hairs for the first three days; then they began to grow smooth, probably having become accustomed to the solution (WIELER **87** p. 376), as the strongest solution was the last one in which they became smooth. The pots were then transposed in various ways to test the effect of change. A transfer from a low concentration to a high one does not seem to be so favorable to hair production as the reverse. The roots seemed to be able to bear higher concentrations of saccharose than of lactose or glucose (cf. LIVINGSTON **44**, p. 295).

In three experiments with glucose in boiled tap water, sunflowers showed very poor growth, 0.5 N being about the growth limit and 0.1 N the limit for hairs.

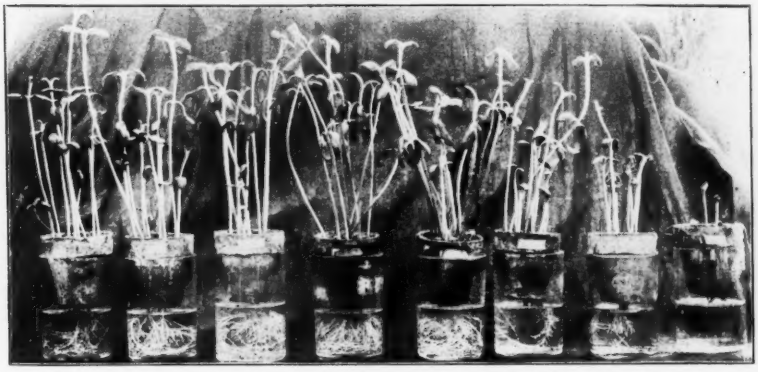
In two experiments with glycerin in boiled tap water with sunflowers, one showed hair limit in 0.05 N and the second in 0.2 N solution. In the latter case one jar had roots haired nearly to the tip.

In two experiments with mannite, sunflowers showed very poor growth, with 0.1 N limit for growth and hairs.

The only electrolytes used were the salts of Knop's solution, and potassium nitrate alone. The modified Knop's solution "D," used by LIVINGSTON (**43**, p. 299), was used for two experiments with sunflower seeds. The best hairs appeared in 0.2 N, where they grew to the ends of the roots. The limit for growth appeared to be 0.4 N and the limit for hairs 0.3 N solution. Sunflower roots passing through the bottoms of pots gave very good hairs in 0.1 N solution, but were not healthy in 0.3 N solution. The unmodified Knop's solution made up with redistilled water was used in various dilutions, 0.1 N being made with distilled and also with tap water, 0.2 N and 0.3 N with tap water, while cultures in redistilled water were used for control. After ten days all but 0.3 N showed some hairs, the best appearing in 0.2 N. The redistilled water gave the zone of hairs which appear in tap water.

In two sets of experiments with potassium nitrate, 0.016N solution gave the best hairs on corn roots. The roots were inclined to be knobby and swollen in the stronger solutions, and the 0.008 N acted

much as water did. *Vicia sativa* seemed more sensitive than corn, for in one set of experiments, performed at the same time as the above, 0.016 N solution killed the root tips and 0.008 N gave the best hairs. Sunflower roots allowed to grow through the bottoms of pots into water and various KNO_3 solutions made with tap water grew best (in average length of roots) in 0.05 N and 0.1 N, 0.4 N entirely stopping the growth of roots. Hairs appeared on all parts of the roots in 0.2 N solution, and more or less on the roots in all the solutions in which the roots grew (*fig. 14*).



H_2O 0.01 0.03 0.05 0.1 0.2 0 3 0.4

FIG. 14.—Seedlings of sunflower growing in a series of KNO_3 solutions.

The ill effects of distilled water on living protoplasm has been shown by LYON (**46**) and LOEB (**45,** p. 67). In my experiments with distilled water the behavior of roots was irregular; sometimes they would grow well, as in one case of Vicia and another of corn; in other cases the primary roots would not grow into it, for example wheat. As a rule, however, distilled water and water redistilled from glass gave less hair than tap water. In one or two experiments with wheat the tips of the roots stopped growing when they entered the water, and laterals were sent out (the longest nearest the tip) and produced some hairs. This peculiar branching was also observed in several cases of corn in distilled water and sunflower roots growing into KNO_3 solution, and even more markedly in the case of wheat

seedlings from which the seeds had been removed, and which were growing in water culture (*fig. 3*). In this last case the laterals were very long. It seems probable that in each of these instances we have to deal with a problem of nutrition, but how cutting off the supply of stored food can cause the tip to branch, as it does when the growth is checked, is not evident.

FOOD.

The possible effect of the quantity of food in the seed upon the development of the zone of hairs in water has been mentioned. SCHWARZ (**75,** p. 162) found that if the food were taken away (how he does not state) or used by acceleration of growth by heat, the hair production ceases sooner than usual, the length of the zone depending on the size of the seed. Several experiments were performed to test the effect of removing the food supply from seedlings. Seedlings of sunflower were cut off at different distances from the tips of the cotyledons and then placed on floating cakes of paraffin so that the radicles passed through into the water. Many died, but of the number which survived the best hairs grew on those with the longest cotyledons. According to TOWNSEND (**79,** p. 518) injury to one part of a plant causes disturbances in others, and the fact that the seeds were mutilated may have had a harmful effect on the root; but from the whole set of experiments it seems fair to say that the greater the food supply the better the hair development.

Among the seeds which show the zone of hairs in water may be mentioned sunflower, corn, white lupine, pea, squash, etc. Others, as oats, wheat, mustard, etc., continue to produce hair in water until the food is exhausted and the plants die. In the case of the plants which form the zone, the cessation of hair production may be due to the hydrostatic pressure of the water; to lack of mineral salts, oxygen, or transpiration; or to the stimulating effect of the water upon growth of the root. Hydrostatic pressure can hardly be the cause when corn roots produced hair continuously in dilute solution of presumably the same pressure as tap water.

OXYGEN.

Although much has been written upon the relations of air and oxygen to growth, here as elsewhere little has been done upon root hairs. The statements of VÖCHTING, PERSECKE, and SCHWARZ seem

to be the only available information on the subject. PERSECKE (**62a,** p. 548) considered the development of root hairs to depend upon the amounts of air and water in the interstices of the soil. WIELER (**86,** pp. 223–4), SCHAIBLE (**74a**), *et al.*, report an increase in the growth of roots as a response to a decreased oxygen pressure. ARKER (**1a**) found that by passing air through water or soil, or by diminishing the air pressure above the soil or water, the roots grew faster. This he thinks was due not to the greater quantity of oxygen but to its greater mobility. The quantity of oxygen necessary for growth according to WIELER (**86,** pp. 213–4) is very small and varies with the plant. He found optimum pressure for *Vicia Faba* to be 5–6 per cent., for Helianthus 3 per cent., a retardation of growth taking place at 0.14–6 per cent. according to the to the plant. VÖCHTING (**82,** p. 94) found the roots of potato tubers to cease producing hair when the oxygen pressure fell to 3 per cent. The growth was slow, therefore the absence of hairs could not in this case be attributed to rapid growth of the roots. VÖCHTING also found (**83,** p. 132) in experimenting with willow twigs that there was sufficient oxygen in water to support life, but not enough for the production of new organs, a supply from above the surface being needed for the production of roots and shoots. WACKER (**84,** p. 110) considered that *Lupinus albus* and *Vicia Faba* died in saturated earth on account of the lack of oxgyen and the presence of harmful disintegration products, and believes land plants not to be able to supply oxygen to the roots by way of the aerial organs. SCHWARZ (**75,** p. 160) tried to overcome the inimical effects of water upon root hair production by passing oxygen through the culture fluid, but did not succeed in producing hairs, and came to the conclusion that other factors than lack of oxygen must be considered.

In the experiments here reported the oxygen content of the medium proves itself an important factor. Comparing corn and wheat in their ability to produce hair in water, we find that under apparently the same conditions the former grows smooth, while the latter produces long and abundant hairs. We may be dealing with the individual ability of the two plants to make use of the same amount of oxygen in a dissolved form, or with the individual needs of the plants for oxygen. Besides, one plant may be better able to supply its roots

with oxygen from the aerial parts than the other. Several experiments to show the effect of diminished oxygen pressure upon the production of root hairs gave similar results and only one need be reported.

A pot of corn, the roots passing through the bottom, was sealed into the top of a jar half full of a solution of pyrogallic acid. The surface of the soil was also covered and sealed with paraffin, leaving a very small hole for watering. Any oxygen entering this hole had to pass through the moist soil before it entered the jar, where it would be absorbed by the acid. In some cultures this hole was plugged up with paraffin without altering the results of the experiment. The oxygen pressure started at normal at the sealing and was gradually lowered to a possible zero. By twenty-four hours the roots were growing smooth, while those in the control jar showed good hairs. The growth was slow, consequently the lack of hair was not due to the rapidity of growth. Suppression of hair was the result when the CO_2 was also absorbed (by KOH), showing that the relative increase of that gas was not the cause of the cessation of hair production. Wheat roots proved to be very sensitive to the lack of oxygen. Several experiments set up as above, but substituting wheat for corn, did not give any result because the roots quickly turned brown and died. In one jar, however, several of the roots lived for a day, elongating in that time from 0 to 4^{mm}. These living roots showed no hair for some distance above the tips.

The experiment with corn was varied in the following manner, to see if the vapor of the pyrogallic acid had the effect upon the hairs. The pot was sealed in as before, the jar, however, being half full of water, boiled and cooled, covered to prevent as much as possible the absorption of oxygen. Air was forced through two jars of pyrogallic acid, finally passing through the water to wash it of any vapor. The apparatus was arranged as shown in *fig. 15*. The jar was measured previously and equal contents marked. The water at first was at *a*, and then the air was passed over slowly, displacing the water to *b*. If the air coming over were entirely free from oxygen, the per cent. in the jar would be half the normal amount. As the rate of passage would determine in great measure the completeness of the extraction of oxygen, an analysis of the oxygen content was not attempted, the aim being more to do away with the acid in the jar, and to get a less

complete extraction of oxygen than in former experiments, than to obtain quantitative results. The oxygen pressure was considered approximately one-half, and the roots indicated about the limit of hair production, showing irregular patches and scattered hairs with bare spaces. Repetition of the experiment showed the same condition of hair production. The temperature varied from 20–24°, which was probably not sufficiently high or low to effect hair production.

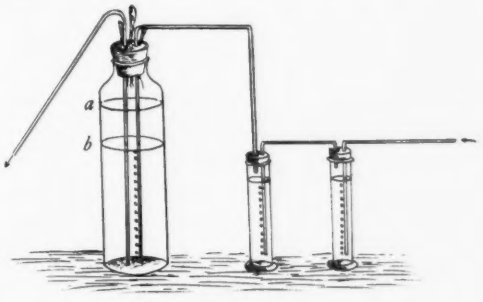


FIG. 15.—Diagram showing apparatus for diminished oxygen pressure; the air passes through two jars of pyrogallic acid solution before entering the experiment jar.

Willow twigs set up in Wolf's flasks in the same manner in about half oxygen content, with their lower ends in water, after three days showed hairs on the laterals in both jars. In seven days there was decidedly less air in the partial pressure jar. Left about two weeks longer, the hairs were better in both jars, appearing better in water than in air. This may be on account of accommodation to lack of oxygen (PFEFFER **64,** p. 2), or more probably to an increase in the supply by the green bark and the chlorophyll appearing in the roots.

GENERAL CONSIDERATIONS.

Many writers (KRAEMER **34**; LEAVITT **40, 41**; VAN TIEGHEM **78**; JUEL **27a**; SAUVAGEAU **72,** p. 5 for Naias and possibly for other forms, **73,** p. 169) associate short cells with root hairs, in most of the cases mentioned the cells being preformed. From many measurements of sections cut from roots grown in these experiments there appeared to be a relation between the length of the cells and the growth of hairs, but there was no evidence of the preformation of the piliferous cells. No definite length of cell can be given as the limit for hair development, either in general or in a single species; the piliferous cells of one root may be longer than the smooth cells of another root of the same species. But an average derived from many

measurements of epidermal cells of roots grown under conditions producing hair is likely to be less than a similar average from the roots of the same species grown under conditions unfavorable for hair production. In the same root the average length of piliferous cells is less than that of smooth cells. SCHWARZ makes the significant statement (**75,** p. 177) that if in the roots of Elodea and Nuphar the short cells do not produce hairs, in time the difference in length is lost, thus indicating that the short cells stretch out if they do not grow into hairs. LEAVITT (**41,** p. 300) reports the same condition for *Nymphaea dentata*. In *Sagittaria Eatoni* (LEAVITT **41,** p. 292) and Phragmites (KRAEMER **34,** p. 22) the difference in size remains when no hairs are formed. The various statements concerning the condition of the root epidermis and the appearance of root hairs in the latter form are far from clear.

From *fig. 4* it will be seen that in corn root the origins of the hairs appear quite near the tip of the root, where the cells are isodiametric (OLIVIER **58,** p. 72). The statement that hairs appear in the zone where the cells have undergone considerable extension (LEAVITT **41,** p. 274) or are just ceasing to elongate (DEBARY **3,** p. 57) does not seem to be true generally. A probable explanation of the conditions observed by these authors is that the growth energy of the cell, after elongation has ceased, finds its expression in the rapid growth of the young papilla, which then takes on the typical appearance of a hair. By marking the roots of a series of corn seedlings growing in moist air, hairs visible to the eye were in several instances observed in the zone of elongation.

As mentioned above, in the plants studied there was no evidence of preformed piliferous cells; all the epidermal cells seemed capable of producing hair, and in corn at times did so. LEAVITT (**41,** p. 296) reports in some members of the Gramineae the whole epidermis to be piliferous. If each cell of the root epidermis is able to produce a hair, what prevents such an outgrowth from taking place? In water roots of corn we find the epidermal cells very much elongated and narrow. This characteristic extends inward through the cortex to the central cylinder, showing that the cells within as well as without are turgescent and stretching nearly equally. *Fig. 5* is a longitudinal section from a root of this water type. If, on the other hand, we

examine a root grown in air, we find the cells shorter and thicker, but not equally so, the outer ones, in all but a few cases to be considered later, being longer and thinner than those near the central cylinder, showing that the former are stretching more strongly than the latter. *Fig. 6* represents a section of such a root, grown in the same experiment as that from which *fig. 5* was taken. Tested with KNO_3 solution, the outer cells of an air root were plasmolyzed in 0.2 N, while the inner cells showed no shrinking, thus indicating that the latter had more concentrated cell-sap and less water. In water roots the epidermal cells were plasmolyzed in 0.2 N and the cortical cells shrank, but the protoplasm did not leave the walls. PFEFFER (**66,** p. 301) reports the turgor of the cortex cells of corn roots in air to be greater than that of the epidermis. In the air roots the epidermal cells seem to have more water, and to be able to stretch more than the inner ones. This can take place to a certain extent, but the inner cells cannot keep pace with them, but hold back the epidermal cells from their full elongation, and the growth energy finds an outlet in the direction of least resistance, *i. e.* the free outer wall. A similar occurrence is noted when Spirogyra is held in a plaster cast (PFEFFER **66,** pp. 240, 385), or when Stichococcus is made fast at the ends (KLERCKER **30,** pp. 94–5).

This bulging takes place in corn near the tip of the root, while the cells are isodiametric, and nearly the whole wall curves at first (*fig. 7*), but with the continued stretching of the cell this primary bulge becomes a papilla. The lagging behind of the inner cells of the cortex during the elongation period allows this papilla to become a hair. It seems then that hairs represent the ratio between the capacity of the epidermal cells to elongate and their ability to do so. If the capacity be the greater, the hairs will be produced; if equal to or less than the ability to elongate, no hairs will be developed. This would limit the statement of SCHWARZ (**75,** p. 155)—"bei dem Maximum der Wachsthumsgeschwindigkeit und unter den günstigsten Bedingungen bildet die Wurzel die zahlreichsten Haar"—to the epidermal cells.

Testing this explanation in the different cases reported here, I suppose first, in the corn roots growing with diminished oxygen supply, that the growth of the epidermal cells is decreased. The

inner cells on the other hand may obtain oxygen from the aerial parts, and thus with less moisture be able to keep pace with the epidermal cells growing with more moisture and less oxygen. In ordinary air the moisture and the oxygen reach the epidermal cells more abundantly than the inner ones, consequently the numerator of the fraction is increased as well as the denominator decreased, and hairs are developed. Upon the upper side of a corn root growing along the surface of water abundant hairs were developed, while the under side remained smooth. The difference in length between the epidermal cells and those of the cortex on the haired side was 20μ, and on the smooth side 6μ. KRAUS's tables (**37,** p. 254) dealing with the lengths of epidermal and cortical cells in relation to hair production are not very complete, and it seems useless to attempt to harmonize the results with those here reported.

KRABBE (**33,** p. 491) reports the inner cells of pith to be less turgescent than the outer ones when placed in water at 1–2°C, on account of the resistance to the passage of water offered by the protoplasts. According to VAN RYSSELBERGHE (**70,** p. 103) the influence of temperature is exhibited not in the total amount of water taken up, but in the rapidity of its passage. In warm water, therefore, the water reaches the inner cells and allows them to elongate sufficiently rapidly to keep pace with the epidermis, which is thus allowed to elongate to its full capacity and shows no hairs.

In the zone of hairs on seedlings in water cultures the available energy and the temporary retardation of growth (evidenced by the short outer and still shorter inner cells, and by the curling of many roots) combine to produce hairs. Also the presence of food may act as a stimulus to cause the cells to divide rapidly and form a thick root, whose inner cells do not get sufficient water, or oxygen, or both, to allow them to elongate as rapidly as the outer ones. Later, in the case of corn, the plumule elongates and probably supplies the inner cells with more oxygen. These are therefore better able to elongate, they are carried further from the food supply, division is less active, the roots grow more slender, the water supply of the inner cells increases, still greater elongation takes place, and the epidermal cells are allowed to stretch to their full capacity. Accommodation to a decrease of oxygen is mentioned by PFEFFER (**65,**

p. 70), and MER (**53**, p. 1279) speaks of the roots becoming accustomed to the medium.

The curving of corn roots in water is, according to Miss BENNETT (**6**) not aerotropic. BEAUVÉRIE (**4**) considers the turning up of water roots to be due to negative hydrotropism, for by using physiologically dry solutions he was able to get them to grow downward. In an experiment in which a slow stream of tap water was passed into the bottom of a vessel in which the roots of corn seedlings were growing, every one turned down, and grew straight and entirely smooth. The stimulus may have been a rheotropic one, or it may have been the presence of fresh aerated water which caused the omission of the hair zone.

An apparent exception to the explanation offered appeared in one root of sunflower grown in 0.5 N saccharose solution, in which the epidermal cells were shorter than the inner ones and still produced hair. Close to the tip, however, the papillae were found on cells shorter than the cortical cells, which makes it seem probable that the epidermal cells on the upper part of this root were shorter than the cortical cells from the start, as is the case with Elodea. In this plant the epidermal cells at the tip are very much shorter than those of the inner cortex, and the difference does not entirely disappear as the root grows older. Consequently there is not the same relation between the epidermal and cortical cells when hair is produced, as there is in corn. Measurements of the cells of roots of Elodea growing in soil, quartz, and water give the following averages in millimeters:

Medium	Cortex	Epidermis	Difference
Soil.....	0.100	0.068	0.032
Quartz.....	0.110	0.077	0.033
Water.....	0.160	0.104	0.056

Upon examination of the table the greatest relative length of the inner cortical cells is seen to be in water, and the least in soil, with the hairs in inverse relation, as was the case with corn.

On the concave side of curved roots of corn the epidermal cells are shorter than the inner ones and at times show more hairs (*fig.*

8). Here the retarding action of the inner cells upon the epidermis is aided by the compression brought about by the curve. SACHS (**71**, p. 466) has shown that the average length of cells in a curve is less than in a straight portion of the root. MACDOUGAL (**49**, pp. 352–3) criticises SACHS' methods and reports the cells on both convex and concave sides longer than those on the same region of a normal straight root. His statement that the hairs are "abundant on the regions apical and basal to the region of greatest curvature, but are also wholly absent from the region exhibiting the shortest radius of curvature," seems to mean that the roots geotropically stimulated elongated at the curve and ceased to produce hair. In curving roots of corn growing in water, the epidermal cells appear to be restricted in their elongation, for curving almost invariably causes hair to develop. SCHWARZ noted this and called it "nutation" (**75**, p. 159). This term did not seem appropriate, and for want of a better word "kinking" has been used in this paper.

Transference from a solution of low osmotic pressure to one of high osmotic pressure appears to withdraw so much water from the epidermal cells that they do not grow into hairs. When the reverse order is followed there is a better chance for the epidermal cells to absorb water and to grow before the inner ones, and in this case some hairs appeared. The problem of the effect of osmotic solutions upon roots is quite different from that relating to filamentous algae and fungi. In the last two cases each cell is bathed in the solution to be tested, while with roots the action of the neighboring cells influences the epidermis, and on account of the thickness of the root the inner ones are not affected just as the outer ones. If a solution could be made which by its osmotic strength or chemical composition would retard the growth of the inner cells and allow the epidermal cells to grow, hairs might be expected. In one or two instances the epidermal cells of roots of sunflower and corn growing in 0.–0.2 N solutions seemed to become accustomed to the solution before the inner cells, and thus were able to grow out as hairs while the growth of the deeper cells was still retarded.

The retarding effect of diminished food supply on the production of hair on the internodes of the stem of potatoes is reported in a short note by KRAUS (**38**). In experiments with half seeds, one or two

cases occurred in which the central cylinder was torn apart at regular intervals by the stretching cortex, the epidermis bearing no hairs. The food supply seemed not enough to give the cells of the central cylinder sufficient strength to retard the stretching of the outer cells.

No change in turgor is needed to explain the appearance of root hairs, for according to PFEFFER (**64**[2], p. 29) there is no change when growth is accelerated by a rise of temperature or by absence of light, or when growth is retarded by lack of oxygen or (**66,** p. 296) by pressure. In the first three cases hairs disappeared or were diminished, while in the last they appeared.

An interesting relation was noticed between the epidermal and the hypodermal cells of some corn roots. In roots growing in the air and producing hair, the nuclei of the hypodermal cells were usually larger than those of the epidermal or cortical cells (*fig. 9*). This may indicate that the hypodermal cells were passing food to the outer cells, the starting of the lateral growth thus initiating a movement of material in that direction. SAUVAGEAU (**73,** p. 171) reports small hypodermal cells under the piliferous cells in Zostera. This demand for food by the outer layer would decrease the supply in the central cylinder and may account for the inverse relation between root hairs and lateral roots, noted by LESAGE (**42,** p. 110), COSTANTIN (**9,** p. 149), MER (**52,** p. 666; **53,** p. 1278), SACHS (**71,** p. 589), *et al.* In Eichhornia the lateral roots extend nearly to the tip, but there are no root hairs. This activity of the central cylinder, contrasted with that of the epidermis, is in harmony with the results of the experiments here reported.

In spite of the structural and functional similarity which often exists between root hairs and rhizoids, it does not seem appropriate to consider them together. In the first place, they are not morphologically similar, rhizoids being of gametophytic origin and root hairs developing from the sporophyte. The fact that rhizoids arise usually from a rather small gametophyte, all the cells of which retain in large measure their primitive condition, may account for the irritability they display toward geotropic, phototropic, and thigmotropic stimuli. Root hairs, on the other hand, are developed on a highly differentiated organ of a highly differentiated sporophyte, and are not thus sensitive, a difference pointed out by HABERLANDT (**22,** pp. 194–5).

It would be well to limit the term "root hair" to hairs borne by morphological roots only.

SUMMARY.

1. Light and darkness appeared to have only an indirect effect, through their influence on growth.

2. High temperature with sufficient moisture tended to decrease hair-production by increasing the elongation of the internal cells.

3. The slower the growth in air the better the hair development.

4. Retardation of growth by glass tubes, by wounding, or by resistance of the substratum favored hair production.

5. Roots of seedling corn in water first curled and produced hair, possibly because of the retardation of growth by the diminution of oxygen or its presence in the dissolved state. Later the roots grew straight and smooth, either on account of accommodation to the oxygen supply or because the gas was supplied by the aerial parts.

6. Saturated air with high temperature tended to suppress hair development (*cf.* 2).

7. Saturated soil tended to suppress hair in corn and wheat, but other factors must be considered when Elodea develops hair in the substratum.

8. Osmotic solutions gave very irregular results on account of some undiscovered disturbing factor.

9. Less hair was developed in distilled water than in tap water.

10. Air deprived of oxygen stopped hair production and retarded growth.

11. Curves and swellings had a favorable effect upon hair development, probably because they represent the retardation of the growth of the root.

12. In all these examples of retardation favoring hair development, not the mere rate of growth, but the differential elongation of the inner and outer cells was of prime importance. Hair production depends on the ratio between the capacity of the epidermal cells to elongate and their ability to do so.

13. The activity of the epidermis may be in inverse proportion to the activity of the central cylinder, lateral roots often appearing when hairs are suppressed, and *vice versa*.

I am under obligations to Dr. H. C. COWLES, under whose direction this work was undertaken; to Dr. B. E. LIVINGSTON for repeated suggestions and kindly assistance; and to Professor C. R. BARNES for his counsel in many of the difficulties that beset me.

STATE NORMAL SCHOOL, FARMVILLE, VIRGINIA.

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EXPLANATION OF PLATE I.

FIG. 1. Longitudinal section of a corn root, grown in a glass tube: *a*, ×45; *b*, two hair-producing cells lapping over the other epidermal cells, ×220.

FIG. 2. *a*, Longitudinal section of a corn root, grown in air; the section shows more than one line of epidermal cells with long and short hairs; ×75. *b*, rounded surface of a living root of corn, grown in redistilled water; the outlines of the epidermal cells were very indistinct; the only case observed where the difference in size was so great; ×45.

FIG. 3. Roots of wheat plants which had been cut from the seeds shortly after sprouting; water culture; ×½.

FIG. 4. Longitudinal section of a root of corn, grown in air, showing the origin of hairs from the region where the cells are still short; ×220.

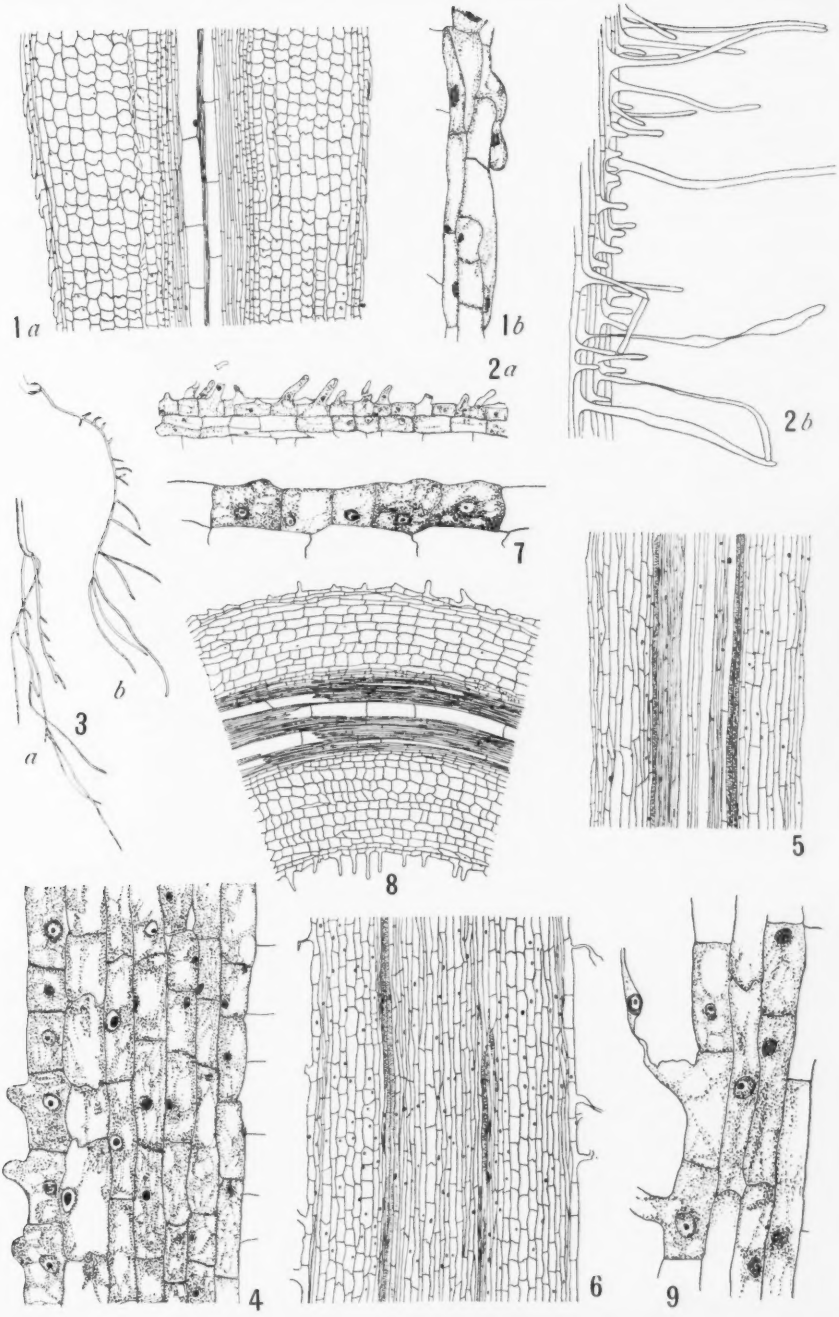
FIG. 5. Longitudinal section of a root of corn grown in water, in the same experiment with the root shown in *fig. 6;* ×45.

FIG. 6. Longitudinal section of a root of corn grown in air, in the same experiment with the root shown in *fig. 5;* ×45.

FIG. 7. Longitudinal section of a root of corn grown in air, showing the beginning of the hairs; ×220.

FIG. 8. Longitudinal section of a corn root curving on the surface of water; ×34.

FIG. 9. Longitudinal section of a corn root grown in air, showing one of the large nuclei of the hypodermal cells; ×220.



SNOW on ROOT HAIRS

A CONTRIBUTION TO THE LIFE HISTORY OF *APOCYNUM ANDROSAEMIFOLIUM*.

THEODORE C. FRYE and ELEANOR B. BLODGETT.

(WITH PLATE II)

IT appears that not one of the Apocynaceae, a family of about 1000 species, has ever been studied carefully in reference to the minute morphology of the flower. Considering this in connection with the fact that the family stands near the Asclepiadaceae, with their peculiar pollen and stigma, it was believed that it deserved investigation. Buds and flowers of *Apocynum androsaemifolium* L. were collected in various stages, and the results of their investigation are herewith described.

The order of appearance of the floral whorls is centripetal. The calyx shows no peculiarities other than a ruffling of the epidermis on the abaxial surface near the base, suggesting a mechanism for the folding of the sepals.

Each petal of the campanulate corolla has on its inner surface near the base a ridge (*fig. 1, r*) running from the midrib diagonally outward and toward its base. It is highest at the midrib, and undoubtedly functions as an aid in compelling cross-pollination. The ridge arises from the more superficial cells of the leaf, and does not affect the course of the veins. Its meristematic crest forms the cells for its enlargement.

The stamens are peculiar in form, adjusting themselves neatly in a ring rather closely applied to the stigmatic head (*fig. 1, s*). At the base of each are two long auriculate appendages (*figs. 1, 2, 3, ap*) extending downwards dorsal to the filament. The sporangia are above the insertion of the filament, and do not extend into the appendages. The loculi open on their inner surfaces, somewhat laterally, by longitudinal slits, and immediately beneath them is a beard of epidermal hairs extending transversely across the faces of the anthers, forming a ring around the stigmatic head (*figs. 1, 2, b*). These hairs meet similar ones from a ring around the head, thus preventing pollen from rolling into the base of the flower.

In the development of the stamen the enlargement of the tip, foreshadowing the formation of sporogenous tissue, occurs just about the time the carpels appear. The hypodermal layer gives rise to a primary parietal layer, and another homologizing with what is ordinarily the primary sporogenous layer (*fig. 4*). The former divides once; the latter also divides, forming the tapetum and primary sporogenous cells (*fig. 5*). This has been observed in a few plants only (**1**), the tapetum usually arising from the primary parietal layer. The primary sporogenous cells elongate as they do in Asclepias (*fig. 6*), but divide into a mass of mother cells, thus reinforcing the presumption that in Ascelpias this stage is simply omitted. The pollen is in the mother cell stage when the ovules appear. The rounded mother cells do not always divide simultaneously. Division of the two daughter cells is simultaneous or nearly so (*fig. 8*), and almost so in all the daughter cells of a sporangium; but not in different stamens of the same flower. Sometimes one daughter cell fails to divide, and three microspores instead of a tetrad is the result (*fig. 9*). Occasionally some of the pollen grains near the tip of the sporangium disintegrate after tetrad division, probably serving as nourishment for the others. The whole tapetum also disintegrates soon after tetrad division.

The microspores remain in tetrads in maturity, and their arrangement with relation to each other is various. In fact, one can find all stages grading from the bilateral to the tetrahedral arrangement. *Fig. 10* evidently resulted from the spindles in the second division being somewhat at right angles in the same plane, and is like a grouping found by WILLE (**2**) in *Orchis mascula*. Usually the four spores are in the same plane, but their arrangement with regard to each other varies; in *fig. 11* four pollen grains meet at a point on each side of the group; in other cases there are four on one side and three on the other; in still others only three meet at a point on either side. The pollen grains in a tetrad are often plainly unequal in size. In such a group as is represented in *fig. 11*, suppose the upper half (cells *a* and *b*) were revolved on the lower half 90°, with *xy* as an axis; if then they adjusted their form to fit each other the result would be the prevailing dicotyl grouping—tetrahedral. *Figs. 11, 12, 13* are three members of a series grading from the bilateral to the tetra-

hedral form, varying only in degree of rotation and in mutual adjustment. Both forms may thus occur in the same plant. However, the tetrahedral form is not common; most of the groups are like *figs. 11* and *12*, similar to those found in *Typha latifolia* (**3**). A case like Zostera (**4**), with its long pollen mother cells dividing lengthwise, makes it doubtful whether pressure is much of a factor in determining the direction of the spindles. The spindles in the microspore daughter cells of *A. androsaemifolium* seem to lack definiteness in direction.

The formation of the generative and tube nuclei occurs when the ovules are in the sporogenous cell stage. The division is not simultaneous in the same sporangium, nor even in the same tetrad; the division is complete by the time the embryo sac has reached its 8-celled stage. The generative cell is lenticular or fusiform, as in Asclepias. Two spherical male cells are formed about the time the embryo sac is ready for fertilization, and while the pollen is still in the anther. STRASBURGER (**5**) observed a small and a large nucleus in the pollen of *Vinca major*, and again found both nuclei in cultures of the pollen tubes. If these were tube and generative nuclei, Vinca differs from *A. androsaemifolium* in the time of the division of the generative cell. STRASBURGER also observed (**5**) a tube nucleus and two smaller ones, probably male cells, in *Amsonia salicifolia*, which seems to indicate that this one agrees with *A. androsaemifolium* in the time of male cell formation.

At the base of each petal and alternating with the stamens are five glands resembling those in Asclepias. They originate shortly after the floral parts appear and are said to be nectariferous (**6**).

The two carpels unite at their tips before ovules are formed, and just after sporogenous tissue appears in the stamens. The tips form a rounded lump or head with glandular epidermis over large portions of it, as in the Asclepiadaceae. The ovules are arranged in the same way as in the family just mentioned, and have the same form. The archesporial cell is of hypodermal origin and does not divide to form a primary parietal cell (*figs. 15* and *16*). A single integument deeply buries the nucellus and primary sporogenous cell. The latter divides into four megaspores, any one of which may become the embyro sac. In *fig. 19* the innermost spore becomes the sac;

in *figs. 17* and *18* it is hard to tell which spore will dominate; and in other cases the spore nearest the micropyle functions. The embryo sac passes through the regular stages to the eight-celled stage. BILLINGS (**7**) figures an embryo sac of *Amsonia salicifolia* with endosperm surrounded by an absorbing layer, and states that *Apocynum androsaemifolium* has no such layer, which we confirmed. A section through the ovules of *A. androsaemifolium* can hardly be distinguished under the microscope from a similar one of Asclepias, so great is the similarity in minute detail.

The pollen rolls out of the anthers upon the head, but is prevented by the pericephalous beard from reaching the stigma which is immediately beneath it. An insect having pollen on its proboscis, reaching after nectar, must insert it between the bases of the anthers, on account of the ridges on the corolla and the basal appendages of the stamens. The proboscis in withdrawal naturally slips into the crevices between the stamens and the head. The sticky, glandular stigma holds some of the pollen, while the pericephalous beard, acting as a brush, increases the probability of pollen remaining at the stigma (*fig. 1*). The head above the beard is glandular and the pollen sticky; therefore as the proboscis is withdrawn through the hairs it picks up a load of pollen for the next flower (*fig. 1*). KUNTH (**6**) gives a short account of the manner of pollination.

The chief facts are the origin of the tapetum from the homologue of the primary sporogenous layer instead of the primary parietal layer; the gradation between bilateral and tetrahedral microspore arrangement; the absence of a primary parietal cell in the ovule; the single layer of cells composing the nucellus; and the great similarity in the internal structure of the flowers of Apocynum and Asclepias.

STATE UNIVERSITY, SEATTLE, WASH.

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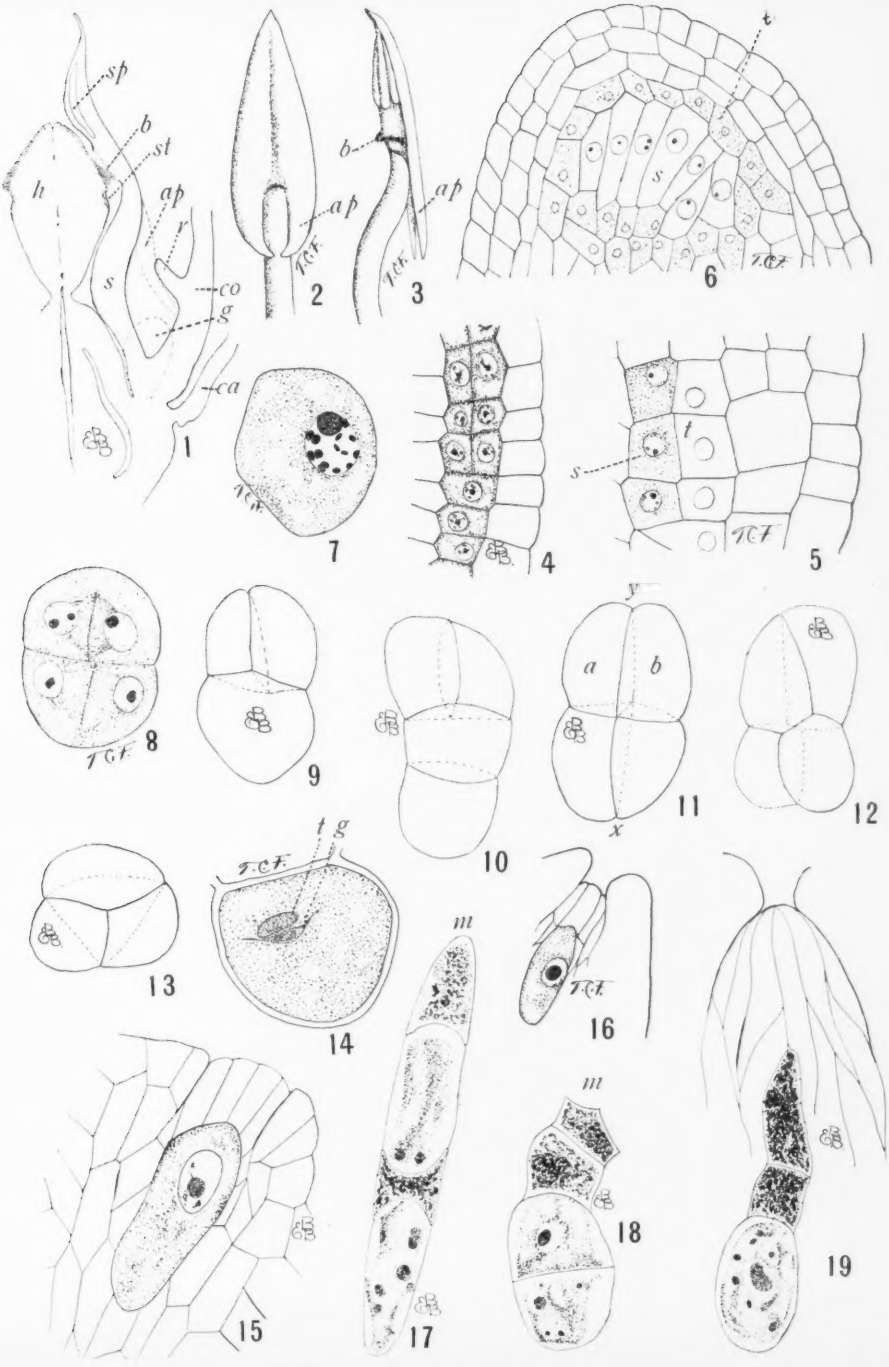

FRYE and BLODGETT on APOCYNUM

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EXPLANATION OF PLATE II.

All figures were drawn with a camera lucida unless otherwise stated, and a Leitz 1–12 oil immersion objective was used for all figures requiring high magnification. The figures have been reduced to one-half the original drawings, to which the indicated magnifications apply.

FIG. 1. Longitudinal section of the flower, semi-diagramatic: *ca*, calyx; *co*, corolla; *r*, ridge; *g*, gland; *s*, stamen; *ap*, appendage; *sp*, sporangium; *b*, beard; *h*, head; *st*, stigma.

FIG. 2. Abaxial view of stamen: *ap*, appendages; without camera lucida.

FIG. 3. Lateral view of stamen: *ap*, appendages; *h*, head; without camera lucida.

FIG. 4. Longitudinal section of anther showing origin of primary parietal layer. ×1800.

FIG. 5. Longitudinal section of anther: *s*, primary sporogenous cells; *t*, tapetum. ×2650.

FIG. 6. Cross section of anther: *t*, tapetum; *s*, primary sporogenous cells. ×1110.

FIG. 7. Microspore mother cell before tetrad division. ×3300.

FIG. 8. Microspore daughter cells in simultaneous division. ×3300.

FIG. 9. Three pollen grains from a mother cell. ×2250.

FIGS. 10–13. Various arrangement of pollen grains in tetrads. ×2250.

FIG. 14. Pollen grain: *t*, tube nucleus; *g*, generative cell. ×2650.

FIG. 15. Section of ovule showing archesporial cell enlarged and functioning as primary sporogenous cell; single integument; nucellus one layer of cells. ×2270.

FIG. 16. Same as *fig. 15;* integument closing. ×1400.

FIG. 17. Four megaspores; first and third disintegrating; *m*, micropylar end. ×3300.

FIG. 18. Four megaspores; first two disintegrating; *m*, micropylar end. ×3300.

FIG. 19. Four megaspores and nucellus; first three disintegrating. ×3300.

CONTRIBUTIONS FROM THE ROCKY MOUNTAIN HERBARIUM. VI.

AVEN NELSON.

SPHAEROSTIGMA F. & M., Ind. Sem. Hort. Petrop. **2**:49. 1835.

Since Dr. JOHN K. SMALL published "Oenothera and its segregates,"[1] much material has been accumulating illustrative of the various species and tending to confirm the wisdom of the earlier generic limitations which were again revived in that paper. In this group of genera, the species of which seem particularly susceptible to differences in environment, we may expect great variation, and therefore naturally differences of opinion as to specific limitations. This has resulted in a rather extended synonomy, which makes studies in the group more than ordinarily difficult. It is not the purpose of the writer to review these genera, but simply to put on record a study of the species of Sphaerostigma, made necessary by the attempt to name some material that came into his hands for examination. This study, in order that it might be the more complete, was extended to the collection of the Missouri Botanical Garden.[2] While listing all the species, there is no necessity for attempting a complete synonomy. SMALL'S paper, cited above, will furnish references to all the important literature on this genus, except that of LÉVEILLÉ.[3] I give therefore only the first use of the present

[1] Bull. Torr. Bot. Club **23**:167. 1896.

[2] Acknowledgment is here made of the uniform courtesy and kindness of the Director, Dr. WILLIAM TRELEASE, in permitting the examination of these valuable specimens—some 200 sheets.

[3] "Monographie du Genre Onothera." I will not attempt to review this very elaborate paper, but since LÉVEILLÉ'S notions of generic limitations are so completely out of harmony with the now accepted ideas of American botanists, it may be permissible to relist the species of the American genus Sphaerostigma. The specimens of Sphaerostigma in the Mo. Bot. Garden Herb. were examined by him and bear his annotations. It is extremely difficult to believe that his grouping of the specimens can stand, especially when one finds that the annotations do not harmonize with the final published list, and that the nomenclature of the illustrations in some instances does not coincide with that of the text.

combination and a reference to what seems to be the first publication of the species or variety.

KEY TO THE SPECIES.[4]

Flowers yellow, sometimes turning red or green.
- Capsules straight.
  - Fusiform ..... 1. *S. andinum.*
    - 1a. *S. andinum Hilgardi.*
    - 1b. *S. andinum minutum.*
  - Narrowly linear ..... 2. *S. filiforme.*
- Capsule more or less curved or contorted.
  - Narrowly linear, cylindrical or nearly so.
    - Curved but not contorted.
      - Ascending.
        - Flowers minute.
          - Capsule short (less than 2^{cm}) .. 3. *S. Nelsonii.*
          - Capsule long (more than 2^{cm}). 4. *S. chamaenerioides.*
        - Flowers 1^{cm} or more in diameter .. 5. *S. campestre.*
          - 5a. *S. campestre helianthemiflorum.*
          - 5b. *S. campestre minus.*
          - 5c. *S. campestre mixtum.*
      - Refracted ..... 6. *S. refractum.*
    - More or less contorted ..... 7. *S. contortum.*
      - 7a. *S. contortum flexuosum.*
      - 7b. *S. contortum pubens.*
      - 7c. *S. contortum Greenei.*
  - Broadly linear, more or less 4-angled.
    - Whole plant glabrous ..... 8. *S. nitidum.*
    - Plant not wholly glabrous.
      - Flowers small (1^{cm} or less broad).
        - Stems virgate, fructiferous to the base.
          - Stem leaves ovate-triangular ... 9. *S. arenicolum.*
          - Stem leaves oblong-lanceolate . 10. *S. hirtellum.*
        - Stems branched from the base .... 11. *S. micranthum.*
          - 11a. *S. micranthum Jonesi.*
          - 11b. *S. micranthum exfoliatum.*
      - Flowers large (more than 1^{cm} broad).
        - Leaves canescently pubescent.
          - Narrowly oblong or oblanceolate ..... 12. *S. bistortum.*
            - 12a. *S. bistortum Veitchianum.*

[4] The following species are not included in this table: *S. angelorum* (Wats.), *S. pterospermum* (Wats.), *S. rutilum* (Davids.).

Ovate to orbicular.....13. *S. spirale.*
13a. *S. spirale viridescens.*
13b. *S. spirale clypeatum.*

Flowers white or rose color.
Leaves glabrous or nearly so.
Bark of stem shining and shreddy.....14. *S. decorticans.*
Bark of stem green.
Capsules evenly distributed.....15. *S. tortum.*
15a. *S. tortum Eastwoodae.*
Capsules interruptedly crowded.....16. *S. tortuosum.*
Leaves not glabrous.
Villous or tomentose.....17. *S. utahense.*
More or less pubescent but not tomentose.
Capsules enlarged at base.
Bark glabrous and shreddy.....18. *S. Boothii.*
Bark hirsute, not shreddy.....19. *S. Lemmoni.*
Capsule not noticeably enlarged at base.
Branches paniculately branched above.....20. *S. Hitchcockii.*
Branches simple above.....21. *S. alyssoides.*
21a. *S. alyssoides macrophyllum.*

1. S. ANDINUM (Nutt.) Walp. Repert. **2**:79; *Oenothera andina* Nutt., T. & G. Fl. N. A. **1**:512.—Not often collected but no doubt of frequent occurrence from western Wyoming westward and northward to Nevada and Washington, where it passes into

1a. S. ANDINUM **Hilgardi** (Greene), n. comb.; *Oenothera Hilgardi* Greene, Bull. Torr. Bot. Club **10**:42.—There is no possibility of maintaining this as a distinct species. No differences except a slightly greener hue and somewhat greater size in all of its parts is perceptible. These differences may well be due to the more vigorous growth induced by the greater moisture and higher temperature in the range of the variety.

1b. S. ANDINUM **minutum**, n. var.—A very diminutive form related to *S. andinum*, with minute flowers, obovate petals, very unequal stamens (the one set almost rudimentary), calyx tube nearly wanting, and the capsule somewhat clavate, tapering to a short pedicel.

The type of this variety is in herb. Mo. Bot. Gard., without data. With the specimens are pencil drawings, showing the above characters, made by Dr. GEO. ENGELMANN, and bearing the herbarium name *Oenothera minuta*. Possibly future collections may show this worthy of specific rank.

2. **S. filiforme,** n. sp.—A diminutive annual 3–5^{cm} high, with filiform stem drooping at summit, and the filiform leaves and capsules more or less secund; ciliate-pubescent throughout; the diminutive flowers yellow; tube of calyx wanting; capsules erect, straight, pubescent, filiform, 1–2^{cm} long.

Type in herb. Mo. Bot. Gard. from New River (Reese's River), Utah, May 28, 1889. Collector not known.

3. S. NELSONII Heller, Muhl. **1**:1; *S. minor* A. Nels., Bull. Torr. Bot. Club **29**:130.—Though Léveillé has seen fit to reduce this, a re-examination of the material at hand simply increases my belief in its validity.

4. S. CHAMAENERIODES (Gray) Small, Bull. Torr. Bot. Club **23**: 189; *Oenothera chamaenerioides* Gray, Pl. Wright **2**:58.—This is a strongly marked species that seems never to be confused with any other.

5. S. CAMPESTRE (Greene) Small, Bull. Torr. Bot. Club **23**:189; *Oenothera dentata* Wats., Bot. Cal. **1**:216.—Variable as to the curvature of the capsule, which is often greatly flexed. The large-flowered form is most frequently collected and may be known as follows.

5a. S. CAMPESTRE **helianthemiflorum** (Lévl.), n. comb.—This is the form of the species which is often distributed as *Oenothera dentata grandiflora* Wats. See plate in Lévl. Monog. opposite 178.

5b. S. CAMPESTRE MINUS Small, Bull. Torr. Bot. Club **23**:189; *Oenothera dentata cruciata* Wats., Proc. Am. Acad. **8**:594.—Often distinguishable from the species with difficulty. Its stricter habit, smaller flowers, and more glabrate stems are characters usually mentioned.

5c. S. CAMPESTRE **mixtum** (Lévl.), n. comb.—Two specimens in herb. Mo. Bot. Gard. have been designated as forms *mixta* and *permixta* by Léveillé, Monog. 180. There seems to be no difference between them except the smaller flowers of the former. Since the former is a much older plant, it may happen that the later blossoms are small. Believing them to be the same, they are here given varietal rank. This variety may be known by the dark green, broadly linear leaves, which are dentate and very numerous, quite crowded and seemingly fascicled upon the short, spreading, or nearly prostrate branches.

6. S. REFRACTUM Wats., Proc. Am. Acad. **17**:373.—Quite distinct, and well-developed specimens are readily recognized.

7. S. CONTORTUM (Dougl.) Walp., Repert. **2**:78; *Oenothera contorta* Dougl., Lehm. in Hook. Fl. Bor. Am. **1**:214.—Why LÉVEILLÉ rejects this and a succession of available names, which he cites as synonyms, does not appear in his monograph. He figures a variety of *O. bistorta* (*O. cheiranthifolia*) as *contorta* Dougl., but even if he were right in thus referring the name given by DOUGLAS, there are yet several other available names. It still remains to be proven, however, that *S. contortum* is not a valid name for *Oenothera strigulosa* T. & G. Fl. **1**:512.

7a. S. CONTORTUM **flexuosum,** n. var.—Small, about 1^{dm} high; branches few, divaricate ascending, usually a pair near the base: leaves linear: flowers yellow; calyx tube obconic: capsule cylindrical, sessile, linear, $2–3^{cm}$ long, variously curved, usually deflexed and again upturned, producing S-shaped forms: seeds smooth.

This was distributed some years since under the herbarium name *S. flexuosum*. No. 4060, named as the type, was secured at Point of Rocks, June 16, 1898. Other specimens are: Nelson, 4698, Granger, Wyo.; Jones, Deep Creek, Utah, June 22, 1891; Genoa (?), Carson Valley, June 17, 1889; Merrill and Wilcox, 602, Pacific Creek, Wyo.

7b. S. CONTORTUM PUBENS (Wats.) Small, Bull. Torr. Bot. Club **23**:189; *Oenothera strigulosa pubens* Wats., Proc. Am. Acad. **8**:594.—Very diverse forms are distributed under this name. The variety probably shades into the species by imperceptible degrees.

7c. S. CONTORTUM GREENEI Small, Bull. Torr. Bot. Club **23**:189; *Oenothera strigulosa epilobioides* Greene, Fl. Francis. 216.—No specimens have been seen by me.

8. S. NITIDUM (Greene) Small, Bull. Torr. Bot. Club **23**:190; *Oenothera nitida* Greene, Pitt. **1**:70.—Perfectly distinct and not to be confused with any other unless it be with *S. spirale*, the canescence of which serves at once to separate them.

9. **S. arenicolum,** n. sp.—Annual, with one main virgate erect stem and 2–4 slender simple ascending-erect branches from near the base; the purplish stem and branches sparsely ciliate-pubescent: leaves crowded, triangular-ovate or narrower, sessile and somewhat clasping by a subcordate base, $1–2^{cm}$ long; root-leaves longer,

oblanceolate and tapering into a slender petiole; all of them hirsute with white spreading hairs: flowers axillary from the base up; calyx tube very short, the lobes lance-oblong, 3–4^{mm} long; petals broadly ovate-oblong, tridentate at the nearly truncate summit, about twice as long as the calyx-lobes, exceeding the longer stamens and about equalled by the pistil: capsules purplish, small and slender, less than 2^{cm} long, variously flexed and somewhat angled: seeds small, pale, smooth, usually oblique at base and obliquely pointed at apex.

I name as type A. D. E. Elmer's no. 3192, Monterey, Cal., distributed as *S. micranthum*. No. 5099, by C. A. Purpus, seems to be the same.

10. S. HIRTELLUM (Greene) Small, Bull. Torr. Bot. Club **23**:190; *Oenothera hirtella* Greene, Fl. Francis. 215.—LÉVEILLÉ in his monograph reduces this to a form of *S. micranthum*, but this does not seem to be justified by his specimens.

11. S. MICRANTHUM (Hornem.) Walp. Repert. **2**:77; *Oenothera micrantha* Hornem. Hort. Hafn.—That LÉVEILLÉ should take up the much later name *O. hirta*, and then reduce to this species such distinct forms as *S. hirtellum*, and *S. Nelsonii*, seems a little strange. However, he has described a very good variety which may be written

11a. S. MICRANTHUM **Jonesi** (Lévl.), n. comb.—Taking as the type the first number cited, viz. Hansen's 543, Amador Co., Cal. 1892, I would name as a close duplicate C. C. Parry's specimens (in the Missouri Botanical Garden) simply labelled "Oenothera. June 1889. Cal." Blanche Trask's Avalon specimen, cited by LÉVEILLÉ, seems rather to belong with the species itself. It is quite probable that the species as it now stands is an aggregate.

11b. S. MICRANTHUM **exfoliatum,** n. var.—Branched from the base, the stems stoutish, the bark white, shreddy, and exfoliating in thin sheets, giving the plant the appearance of *S. decorticans:* pubescence of the stems ciliate, that of the leaves and fruits closer and somewhat appressed: capsules sharply angled, contorted.

I cite here the following specimens: C. R. Orcutt, Colorado Desert, April, 1889; C. A. Purpus, no. 5083, Erskine Creek, Cal., 1897.

12. S. BISTORTUM (Nutt.) Walp., Repert. **2**:77. *Oenothera bistorta* Nutt., T. & G. Fl. N. A. **1**:508.

12a. S. BISTORTUM **Veitchianum** (Hook.), n. comb.; *Oenothera bistorta Veitchiana* Hook., Bot. Mag. *pl. 5078*.—The characters

which were supposed to distinguish this variety sufficiently from *S. bistorta* and to constitute it a species become less well-defined the larger the series of specimens. Even the greater length of capsule and beak seems to be a variable quantity.

13. S. SPIRALE (Lehm.) Fish. & Mey., Ind. Sem. Hort. Petrop. **2**:50; *Oenothera spirale* Lehm. in Hook. Fl. Bor. Am. **1**:213.—Assuming it to be a fact that this Californian plant is distinct from *S. cheiranthifolium* of South America, the specific name as given by LEHMAN in Hooker's *Flora* is the next available one.

13a. S. SPIRALE **viridescens** (Lehm.), n. comb.; *Oenothera viridescens* Lehm. in Hook. Fl. Bor. Am. **1**:214.—If this be a good species, it certainly is very difficult to distinguish from the preceding. It was given only varietal rank by WATSON in his revision (Proc. Am. Acad. **8**:592), under the name *suffrutescens*—the woody base and possibly perennial duration, with the somewhat larger flowers, being the characters that he used. But even in these respects the species and the variety seem to grade into one another.

13b. S. SPIRALE **clypeatum** (Lévl.), n. comb.; *Oenothera clypeata* Léveillé, Monog. Oenothera, 222.—Distinguishable by the broad, shield-shaped leaves which are densely canescent, and by the large flowers (often 4^{cm} across).

14. S. DECORTICANS (H. & A.) Small, Bull. Torr. Bot. Club **23**:191; *Gaura decorticans* H. & A. Bot. Beech. Voy. 343.—SMALL seems to be well within bounds when he assigns priority to the name of HOOKER and ARNOT. The species, though apparently greatly variable, is so merely before it begins to blossom when quite small, at which time it is smooth and erect. With age it becomes large, more spreading, and roughened with the loosened shining shreddy bark. WATSON'S characterization of the seeds as "cellular-pubescent" is a good one.

15. S. **tortum** (Lévl.), n. sp.; *Oenothera chamaenerioides torta* Lévl., Monog. Oenothera, 230; *O. alyssoides minutiflora* Wats., Proc. Am. Acad. **8**:591.—Branched from the base and spreading, becoming at length nearly prostrate; leaves glabrous, mostly basal, oblanceolate and tapering into slender petioles: capsules about 2^{cm} long, cinereous, variously contorted.

LÉVEILLÉ is right in allying this with *S. chamaenerioides*, but on habit alone, to say nothing of the fruits, it is entitled to specific rank.

Following are specimens illustrating: Jones, 5548, Manti, Utah; Nelson, 4691, Granger, Wyo.; Cusick, 2515, Malheur River, Oregon; Trelease, 4435, Shoshone, Idaho; Nelson, 4707, Green River, Wyo.; Godding, Milford, Utah.

15a. S. TORTUM **Eastwoodae,** n. var.—Leafy throughout, the leaves oblong-linear: flowers very small: capsule tapering into a slender beak, spirally coiled at base.

This is probably a good species. Only one specimen is before me: Alice Eastwood, Grand Junction, Colo., May, 1892.

16. S. TORTUOSUM A. Nels., Proc. Biolog. Soc. **17**:95. 1904; *Oenothera gauraeflora caput-medusae* Lévl., Monog. Oenothera, 226. —LÉVEILLÉ'S plate shows only a single branch from Lemmon's specimens.

17. S. UTAHENSE Small, Bull. Torr. Bot. Club **23**:191.—Whitened with a tomentose pubescence, branching from the base upward, 15^{cm} or more high (the plants in hand are all young): leaves ovate, obovate, or oblanceolate, $2–4^{cm}$ long, generally tapering to a short petiole: flowers crowded in terminal somewhat corymbose racemes, white; calyx-tube longer than the lanceolate lobes; petals obovate, 5^{mm} long, longer than the stamens but surpassed by the pistil: capsule linear, less than 2^{cm} long, more or less contorted.

The specimens before me were collected by L. N. Goodding at Milford, Utah. As the original description calls for yellow flowers I thought at first Goodding's specimens were another species, but agreeing in most other respects I am going to assume that "flowers yellow" was a clerical error.

18. S. BOOTHII (Dougl.) Small, Bull. Torr. Bot. Club **23**:191; *Oenothera Boothii* Dougl., Lehm. in Hook. Fl. Bot. Am. **1**:213.—Seemingly seldom collected. Typical specimens by L. F. Henderson, Shoshone Falls, Idaho, July, 1897. Many of the specimens referred to this species belong to the next.

19. **S. Lemmoni,** n. sp.—Branched from the base up, $2–3^{dm}$ high, stem and branches rather stout, crinkled-hirsute; branches divaricate-ascending: leaves rather large, variable in size, $2–5^{cm}$ long, oblong or broader, mostly acute at apex, lower tapering into petioles, hirsute-ciliate especially beneath: flowers in a crowded terminal short-hirsute raceme, lengthening into a bracteate fruiting spike; calyx tube but slightly enlarged upward, scarcely as long as its narrowly lanceolate lobes; petals broadly obvate or suborbicular,

about 7^{mm} long, slightly longer than the calyx lobes and stamens, equalling the style; stamens similar and equal: capsule slender, tapering to summit, ascending, somewhat bent or contorted, about 2^{cm} long.

This has passed as *S. Boothii* Dougl. Similar as the descriptions seem, the two plants are quite distinct in appearance. *S. Boothii* is glabrous and with shreddy bark on the older stem; it branches mainly near the base, the branches also branching; its flowers are much smaller, and the capsules are shorter and more contorted.

The type is J. G. Lemmon, no. 103, eastern flank of Sierra Nevada, Cal. 1875. Two good specimens, both in herb. Mo. Bot. Garden.

20. **S. Hitchcockii** (Lévl.), n. sp.; *Oenothera gauraeflora Hitchcockii* Lévl., Monog. Oenothera, 226.—Softly hirsute or ciliate, branched from the base, $15–25^{cm}$ high; branches slender and more or less paniculately branched above: root leaves oblong, irregularly dentate, about 3^{cm} long, tapering into a petiole one-half as long; stem leaves smaller, bract-like, sessile, broadly linear or lanceolate: flowers crowded in bracteate secund racemes; calyx tube slender, scarcely enlarged at summit, as long as the linear-lanceolate lobes; petals white, obovate, $3–4^{mm}$ long, scarcely longer than the calyx lobes and the stamens; style slender, longer than the petals: capsules slender, $12–18^{mm}$ long.

This very excellent species rests upon two specimens in herb. Mo. Bot. Garden. One bears the data "Simpson Park, July 6th, 1859 (?)," and in pencil "nothing like it known to me;" the other is blank, but both look as if they were from the same collection.

21. S. ALYSSOIDES (H. & A.) Walp., Repert. **2**:78; *Oenothera alyssoides* H. & A., Bot. Beech. Voy. 340.

21a. S. ALYSSOIDES MACROPHYLLUM Small, Bull. Torr. Bot. Club **23**:192; *Oenothera alyssoides villosa* Wats., Proc. Am. Acad. **8**:591.

The following are, so far as the writer knows, still unknown except from the original specimens and descriptions. So far as one may judge from descriptions, they are valid and will no doubt again come to light.

S. ANGELORUM (Wats.), *Oenothera angelorum* Wats., Proc. Am. Acad. **24**:49.

S. PTEROSPERMUM (Wats.); *Oenothera pterosperma* Wats., King's Rep. 112.

S. RUTILUM (Davids.); *Oenothera rutila* Davids., Erythea **2**:61.

COOPER'S COLORADO COLLECTIONS.

In the summer of 1904, Mr. WILLIAM S. COOPER, a student in Alma College, Michigan, spent some weeks in Colorado collecting in the vicinity of Estes Park and upon Long's Peak. He secured over 300 numbers, many of them of great interest. The following I will characterize as new:

Oreocarya pulvinata, n. sp.—Cespitose-pulvinate, practically stemless, the small cushions a few centimeters across and about 1^{cm} high; flowers as well as the leaves involved in the soft villous pubescence: leaves crowded, broadly linear, less than 1^{cm} long: flowers few, glomerate at the summit of the reduced stems (the stems scarcely rise above the matted leaves): calyx-lobes linear, nearly equaling the corolla tube: corolla white; its tube dilated, subspherical, about 2^{mm} long, the broad throat only partly closed by the conspicuous crests; the lobes of the limb suborbicular, about as long as the tube: stamens small, included, inserted near the middle of the tube; filament almost wanting: style short, rather thick, equaling the stamens.

This species so closely simulates *Eritrichium aretioides* (before the flower stalks of that species have developed) that one would almost certainly pronounce it an Eritrichium at the first glance. The pubescence and pulvinate habit are similar, but a glance at the flowers does not leave one in doubt very long.

The type material, no. 278, is very scanty, but so characteristic a species cannot be ignored. Collected on Mummy Mts., Estes Park, Aug. 12, 1904, alt. $12–13{,}000^{ft}$.

Chrysopsis Cooperi, n. sp.—Whitened with soft loose long-villous pubescence throughout: stems low, spreading, more or less decumbent at base, $10–15^{cm}$ high, leafy throughout: leaves narrowly oblanceolate, tapering into a margined petiole-like base, from $2–5^{cm}$ long, middle and upper stem leaves usually longer than the basal: heads solitary, terminal and axillary; terminal head large, $12–14^{mm}$ high and considerably broader, subtended by some foliar bracts which are long-ciliate on the margins; axillary heads reduced downward, on successively shorter leafy peduncles, usually only the 2 or 3 uppermost developing, the others becoming sessile and aborted

in the axils: involucral bracts narrowly linear, acute, midrib green and the margins scarious: rays 15–25, orange-yellow, ligule 12–15^{mm} long; disk corollas numerous, with very slender tube which is shorter than the narrowly tubular throat; teeth short, lanceolate, erect: pappus dingy, equaling the corolla: akene short-linear, minutely silky-pubescent.

This is probably to be compared with *C. alpicola* Rydb. and *C. Bakeri* Greene, but it is far more silky-hirsute than either. It seems to be unique in the axillary heads, which though usually aborted can be detected in the axils nearly down to the base of the stems.

Cooper's no. 50, Long's Peak, near timber line is the type; August 11, 1904.

CHRYSOPSIS ALPICOLA **glomerata,** n. var.—Closely resembling the species and like it nearly devoid of basal leaves at anthesis: heads several, closely glomerate at the summit of the simple stems.

Founded on Cooper's no. 174, Estes Park, August, 1904.

Aster Cordineri, n. sp.—Spreading by horizontal rootstocks, dark green and seemingly glabrous to the unaided eye, under a lens minutely but very sparsely scabrous (mostly on the margins of leaves and involucral bracts): stems 3–6^{dm} long, generally simple below, racemosely short-branched above, decumbent at base and either widely spreading or nearly erect, often puberulent especially upward, very leafy: leaves broadly linear, crowded, spinulose tipped; primary ones 4–7^{cm} long, 4–6^{mm} broad; secondary ones similar but smaller, more or less fascicled in the axils: heads solitary at the ends of the short leafy axillary racemosely disposed branchlets, rather large: involucre nearly 1^{cm} high, somewhat broader than high; bracts erect, glabrate, dark green on the spatulate-linear blade, lighter at base, spinulose tipped: rays 20–30, bluish shading to white: pappus rather coarse and dingy: akene short-pubescent.

A very characteristic species related to *A. commutatus*. Readily distinguished by its glabrate dark green appearance and the relatively few large solitary heads. The branchlets are strictly racemose, only 3–5^{cm} long, and those on the stems, which are widely spreading, are assurgent and therefore secund in appearance. Two collections are at hand. The first was secured at Myersville, Wyo., on the Sweetwater, Sept. 5, 1894, by Mr. George Cordiner, the writer's first enthusiastic field assistant;[5] the second is Cooper's no. 151 (type) from Estes Park, Aug. 11, 1904.

[5] Mr. Cordiner was accidentally killed in 1895 by a falling wall at a fire where he was assisting. I name this plant in memory of a young life of great promise.

Crepis alpicola (Rydb.), n. sp.—Caudex short, vertical, semifleshy: leaves glabrous, rosulate on the crown, linear-oblong or oblanceolate, acute at apex, sessile or tapering into a short margined base, entire or saliently toothed or even subruncinate, 3–6^{cm} long: stems scapose, simple, glabrous, with one or two linear bracts, 10–20^{cm} high, usually monocephalous: involucre about 14^{mm} high, dark green, clammy or glandular pubescent; its bracts in 3 or 4 successively shorter rows: ligules 2^{cm} long: akenes short, fusiform, shorter than the fine white pappus.

This is probably *C. runcinata alpicola* Rydb., Bull. Torr. Bot. Club **24**: 299, although the above description does not quite tally with the brief diagnosis of the variety. A reasonable amount of variation will account for any differences. It is to be compared, however, with *C. riparia*, because of its large heads and the gland-tipped pubescence on the involucre. It is distinct from that species in its small glabrous leaves, its one-flowered stems, its involucre of 3 or 4 rows of bracts, and its short fusiform akenes. Cooper secured it in an alpine meadow (11,000^{ft}) on Long's Peak, Aug. 3, 1904, no. 218.

MISCELLANEOUS SPECIES.

Gilia exserta, n. sp.—Biennial, 2–3^{dm} high: stem single at base but branched from near the base upward; branches mostly simple and moderately divaricate, almost equaling the main stem, minutely pruinose-viscid: leaves 2–5^{cm} long, somewhat pungent, linear, entire or simply pinnatifid, with few to several linear lobes: flowers in small bracteate cymes forming narrow panicles: calyx membranous, narrowly campanulate, about 4^{mm} long, merely pruinose; its teeth very short, green, triangular-subulate, and minutely pungent: corolla white, purple dotted, 10–12^{mm} long, somewhat trumpet-shaped; tube surpassing the calyx; its lobes elliptic-oblong, acute, almost as long as the tube: stamens noticeably exserted; style scarcely so: ovules about 2 in each cell; seeds destitute of mucilage.

The type is no. 538, by C. F. Baker, Pagosa Springs, Colo., July 28, 1899. It was distributed on GREENE's determination as *G. multiflora* Nutt., which it certainly cannot be. It seems nearer *G. stenothyrsa* Gray of the section GILIANDRA (Syn. Fl.).

Amelanchier oreophila, n. sp.—A low scraggy-branched shrub, 1–2^{m} high, growing mostly in close clumps: young leaves, petioles, and twigs more or less lanate-pubescent, some of the pubescence persisting till maturity, especially on the lower face of the leaves:

leaves ovate, obovate, or broadly elliptic, rather small, not more than 3–4^{cm} long even at maturity, incisely small-toothed from the middle to the obtuse or rounded apex, on petioles usually less than half as long as the blade: racemes short and dense: calyx-lobes subulate-triangular, lanate-pubescent on the margins and inner face, the pubescence persisting nearly or quite till maturity: petals spatulately oblanceolate, short (about 8^{mm}): pome globose, purplish black, developing but little pulp, and remaining rather dry and insipid, maturing late (September ?).

This is a segregate from *A. alnifolia* Nutt. I think most collectors must have felt that either *A. alnifolia* was unusually variable or that some segregation ought to be made. After many years' observation in the field and the study of a large series of specimens, I am satisfied that two valid species exist and can be readily distinguished. Nuttall's *A. alnifolia* is the widely distributed glabrous shrub of the creek banks, moist cañons, and snow slopes. At maturity it is perfectly glabrous and is quite glabrous from the beginning upon the calyx lobes. The leaves are larger, coarsely serrate, often suborbicular or with a tendency to truncateness at base and apex. The petals are much larger (12–15^{mm} long). The fruits become much larger, are purple, with bloom, juicy and well flavored, are used extensively for sauce and pies, maturing during July or August according to the altitude.

A. oreophila is a smaller shrub, scraggy-branched, usually in dense clumps, and occurring in the driest situations (open stony slopes, ridges, and hilltops). It is never wholly glabrous, and the fruit is of little if any value. Many other differences are brought out in the characterization. Much of the material distributed from the Rocky Mountains belongs to this species. I may cite the following as at hand.

COLORADO: L. N. Goodding, 1456, Camp Creek, Routt Co., July 6, 1903; 1683, Willow Creek, Routt Co., July 25, 1903; Rydberg and Vreeland, 6030, La Veta, May 18, 1900; K. K. MacKenzie, 240, Breckenridge, Aug. 1901; C. F. Baker, 55, 139, and 380, Plants of West Central Colorado, 1901. WYOMING: By the writer, 2954, Evanston, May, 1897; 117, 6968, and 6985, Albany Co.; L. N. Goodding, 555, Elk Mt., Aug. 21, 1901; Merrell and Wilcox, 458, Point of Rocks, June 17, 1901. The following are allied, but when better known will probably be found to represent two other species: Baker's Plants of Nevada, nos. 946 and 1002; Mrs. R. W. Summers, specimens from Yamhill, Co., Oregon, March, 1903.

Amelanchier elliptica, n. sp.—A low shrub or more rarely a small tree, growing mostly as scattered individuals rather than in clumps: branches and twigs rather slender and willow-like, gray except at the tips which are purplish-black with an inconspicuous beady resin:

most of the leaves elliptic in outline, incisely serrate, with rather small teeth extending to the middle or sometimes nearly to the base, nearly glabrous above from the beginning, lightly floccose woolly beneath when young as are also the slender petioles: inflorescence few-flowered, quite open in blossom and more so in fruit: calyx somewhat woolly-pubescent, its lobes deltoid-triangular, shorter than the tube, lanate on the inner face: petals narrowly oblanceolate, 12–15^{mm} long: mature fruit not known, the half-grown fruit spherical.

This will also have to be considered as a segregate from *A. alnifolia*, from which it differs noticeably in its elliptic leaves, the teeth of which are smaller and sharper and point toward the apex. The woolly pubescence of leaf and flower at once calls attention to this as distinct from the thick-leaved glabrous *A. alnifolia*. *A. elliptica* seems to be a species of wet places in the mountain parks and open stream banks. The species is again noticeable because of its few large flowers which are well exserted from the leaves. It is as handsome a species when compared with *A. alnifolia* as is *A. florida* when compared with *A. Cusickii*.

I take as the type L. N. Goodding's no. 1447, Beaver Creek, Larimer Co., Colo., July 4, 1903. The following also seem to belong here: Goodding, no. 1036, Milford, Utah, June 5, 1902; Baker, Earle, and Tracy, no. 197, Bob Creek, Colo., June 28, 1898; possibly the following also: Jones, no. 1447, City Creek cañon, Utah, June 5, 1880; Baker's West Central Colorado Plants, 1901, nos. 47 and 260 (in my set distributed unnamed).

THE ROCKY MOUNTAIN HERBARIUM,
LARAMIE, WYOMING.

BRIEFER ARTICLES.

THE VIENNA CONGRESS.

THE SECOND International Botanical Congress was held at Vienna, June 11–18, 1905, and was highly successful in every way. There was a large and unusually representative attendance, the list of members containing about 600 names. Deducting ladies registered with husbands or relatives, and the considerable number of amateurs from Vienna and the neighborhood, it is certainly safe to say that there were present nearly 400 professional botanists. Of that number nearly one-half would be known by name to any one familiar with botanical literature, and among these were many whose reputation is world-wide. Naturally Austria was most numerously represented, but Germany sent a large contingent, and nearly all the European countries were represented, except perhaps those of the Iberian and the lower Balkan peninsulas. The English were few—a half dozen at most. Sixteen American botanists were present: ARTHUR, ATKINSON, BARNES, BARNHART, BLAKESLEE, BRITTON (Mr. and Mrs.), BROWN, CAMPBELL, COVILLE, DUGGAR, ROBINSON, SHEAR, TRELEASE, UNDERWOOD, and WOODS. But American societies were sadly negligent, and many were unrepresented which might have delegated authority to some of the sixteen.

The Congress was opened in the *Festsaal* of the University by WIESNER, with addresses of welcome by the minister of agriculture, speaking for the emperor; by the burgomeister, for the city; and by the rector for the university. BONNET, secretary of the Paris Congress, gave a historical statement of the organization of the present congress, and REINKE (Kiel) delivered an address on *Hypothese, Voraussetzungen, Probleme in der Biologie*.

In the afternoon the Nomenclature Conference organized in the hall of the Museum in the Botanical Garden by electing as president FLAHAULT; as vice-presidents RENDLE and MEZ; and three secretaries; received the report of the standing committees and of the *Rapporteur général* (BRIQUET); and adopted rules of procedure. The report of the Commission was presented as a quarto of 160 pages, having the text of the code of 1867 in the first column, the new formal proposals of various bodies in the second, notes by the *Rapporteur* in the third, and the text

recommended by the Commission in the fourth. This *texte synoptique* was the work of BRIQUET, whose arduous labors for the past five years thus made possible the revision of the rules of nomenclature by this Congress. His untiring industry, unfailing patience, uniform courtesy and impartiality, as well as his linguistic facility won the admiration of all.

Afternoon sessions thereafter, from 3:00–7:00 or even later, were devoted to the discussions and actions of the *texte synoptique*.

Morning sessions and on some days also afternoon sessions, which were held in the lecture-room of the Engineer-Architects Club, were devoted to addresses upon special topics. Thus on Tuesday there were six papers on the development of the European flora since the Tertiary period; two introductory, on the geographical problems by PEACK (Vienna) and the botanical problems by ENGLER (Berlin), while ANDERSSON (Stockholm) spoke specially for the Scandinavian peninsula, WEBER (Bremen) for the north German lowlands, DRUDE (Dresden) for the mountainous region of central Germany, and BRIQUET (Geneva) for the alpine reigon.

On Thursday the topic was the present position of the doctrine of photosynthesis, MOLISCH (Prag) speaking of photosynthesis in chlorophyllous and HUEPPE (Prag) in chlorophyll-free organisms, KASSOWITZ (Vienna) giving a short talk on photosynthesis from the standpoint of metabolism. After a brief intermission the general problems of regeneration were discussed by GOEBEL (Munich), LOPRIORE (Catania) presenting a more special paper on the effects of wounding on regeneration of stems and roots. In the afternoon there were papers by ARTHUR (Lafayette) on the classification of the Uredinales; by ISTVÁNFFI (Budapest) on the life history of *Botrytis cinerea*, and by PETTKOFF (Sofia) on the algal flora of Bulgaria.

On Friday SCOTT (Kew) spoke on the fern-like seed plants of the carboniferous flora; LOTSY (Leiden) on the influence of cytology on taxonomy; and HOCHREUTINER (Geneva) on the Botanical Garden at Buitenzorg.

In the afternoon and on Saturday papers were mostly ecological: BECK (Prag), the significance of the *Karstflora* upon the development of the central European flora; DRUDE (Dresden), suggestions for an agreement upon the terminology of phytogeographical formations, and terminology used in the cartography of plant formations; WILLE (Christiania), Schübeler's theory as to the changes which plants undergo in acclimatization at higher latitudes; TANFILJEFF (St. Petersburg), the Russian steppes; TSCHERMAK (Vienna), the production of new forms by crossing; ADAMOVIĆ (Belgrade), phytogeography of the Balkan peninsula; PALACKY

(Prag), genesis of the African flora; KURTZ (Cordoba), the fossil flora of Argentina; BORBÁS (Klausenburg), the stipas of Hungary; HUA (Paris), report on the establishment of a new international organ for the publication of new names; SCHINDLER (Brünn), regulatory processes in the plant body in relation to cultivation.

On Wednesday a meeting of the *Association Internationale des Botanistes* was held, at which reports of the treasurer and secretary were presented. The most important action taken, by an overwhelming majority, was the direction of the Executive Committee, as soon as the present contracts permit, to print all *résumés* in type of the same size, abandoning the attempted discrimination. The next meeting will be held in Montpellier in 1908. The new officers are WETTSTEIN, president; FLAHAULT, vice-president; the present secretary and treasurer were re-elected.

The botanical exposition, under the auspices of this Association, occupied the Orangery at Schönbrunn, the emperor's summer palace on the outskirts of the city. The horticultural exhibit was open only during the week of the Congress, but the other exhibits remained for two weeks. There was an historical section, comprising books, atlases, original drawings, engravings, portraits, busts, herbarium specimens, instruments, and preparations of historical interest. This portion of the exhibits was limited to Austria, and naturally the most important contributors were the botanical section of the Imperial Museum of Natural History, and the two botanical institutes of the university.

The largest section of the exposition consisted of modern appliances for instruction and research. With many of the instruments demonstrations were given daily (10–12). In this section were shown living cultures of algae fungi, and bacteria; photographs of plants and plant-formations, and microphotographs of immense variety and all sizes, including many lantern slides; drawings and paintings; wall charts and maps; current books by the publishers; exsiccatae; and apparatus of many kinds (microscopes and their accessories, balances, ovens, and baths, glassware, physiological instruments, seed-control and wood-testing appliances, etc.

Particularly noteworthy in this section was a display of materials actually used in the *Realschule* and *Gymnasia* for botanical instruction, "whose purpose," the exhibitors say, "is to put before the eyes of visitors the advance which botanical instruction has made in the last decades. . . . . Inasmuch as the phenomena of plant life must be brought close to the interest and understanding of pupils there stands in the foreground of the display the apparatus for conducting experiments in plant physiology, which break the path for the understanding of biological processes. Then come

models and preparations for elucidating the anatomical and morphological features. . . . ." This exhibit shows clearly how thorough and wise the courses are. The equipment puts to shame all of our high schools and nine-tenths of our colleges.

The unique mechanical balances of NĚMETZ; the living algal cultures of the Biological Station in Vienna; the apparatus and methods of the imperial Seed-control Station in Vienna, and of the Imperial Forestry Station in Mariabrunn; and the display of pure cultures of fungi by the bureau established for this purpose by the *Association Internationale des Botanistes* (in Utrecht, in charge of Professor F. A. F. C. WENT) deserve special mention. The attempt of the Association to secure an exhibit of separates and works of many writers was practically a failure, only eleven sending papers. As a whole the exhibition was highly interesting and useful.

The third meeting of the *Freie Vereinigung der Systematischen Botaniker und Pflanzengeographen* also occurred on Wednesday, at which, in addition to a considerable list of papers, there was held a discussion on the introduction of a uniform nomenclature in phytogeography.

On Friday the agricultural botanists came together in the imperial Station for seed-control, in the Prater. No papers were read, but discussions were held on several topics, such as: methods of investigating sugar-beet seeds; weighing methods in determinations of germinative capacity; organization in seed-control stations; culture and study of barley; etc.

The actions on nomenclature are too extensive to summarize, and only a few of the more important decisions can be mentioned here. The word *laws* is to disappear, *rules* and *recommendations* taking its place. The rules for nomenclature of "cellular cryptogams," *i. e.*, the Bryophyta and Thallophyta, are remanded to a special commission of specialists, which is to present recommendations to the Congress of 1910, to be held at Brussels. In like manner a report on rules for the nomenclature of fossil plants is to be made by a Commission of paleobotanists. The word *ordo* (order) displaces *cohors*, recommended by the Commission for a group of families; but the American proposition to substitute *phylum* for *divisio* was lost. The date 1753 Linn. Sp. Plant. ed. 1. was adopted by a vote of 150 to 19. A vote on an article permitting laxity in the application of the rule of priority to generic names, and providing for a list of genera to be maintained *en tous cas*, was 133 yeas, 36 nays. Later, HARMS's list of such genera (400 and over) was adopted by a vote of 118 to 37. This list had been referred to a committee composed of BONNET, HARMS, BRITTON, PRAIN, and BRIQUET, and was recommended (by a majority) for adoption.

Some amusement was caused by the proposal of two corrections by the author while the motion to adopt was pending.

The proposition to except some old family names for the rule requiring such names to be derived from an important genus was carried by only 101 to 62.

The voting in regard to publication of a new species by plates and exsiccatae was confused, and the article was referred back to the Commission for editing. It is intended to exclude as valid publication *in future* plates without diagnoses, and past plates (without diagnoses) which contain no analytic drawings. Citation in synonymy and accidental mention are also declared invalid as publications. It was agreed (184 to 2) to adopt the compromise reported by a conference committee requiring the name of a section or species when transferred to another genus, or the name of a variety when transferred to another species, to be preserved or *re-established;* but when the rank is changed the preservation of the name is optional, and if not preserved its later re-establishment is not permissible. This is accompanied by a *recommendation* to preserve the primitive name whenever possible.

The vote on the use of double names (like *Linaria Linaria*) was unexpectedly close; 116 against them and 72 in favor. Generic names differing merely by their last syllable and even by one letter will be retained. Only typographic or orthographic corrections may be made in generic names.

After January, 1908, diagnoses must be written in Latin; so a close vote, 105 to 88, decided on Friday. A vote to reconsider was made on Saturday but was lost, 125 to 56. The metric system is recommended, and it is declared that "the foot, inch, line, pound, ounce, etc., should be rigorously excluded from scientific language." Fathoms, knots, and marine miles likewise fall under the ban. Authors are requested to indicate clearly the scale of magnification of figures.

On the whole the action of the Congress was conservative from the American point of view, yet marks great progress toward a stable nomenclature. Our European friends have not yet grasped the idea of generic types, and the rules relating to genera will doubtless be the next region of advance. When the final editing is accomplished and the new code is available, we may reasonably expect the rules to be generally followed until a further revision is possible.

The work on cryptogams and fossil plants will doubtless be prosecuted with vigor. The Commission of Cryptogams consists of MIGULA, LISTER, LAUTERBORN, GOMONT, WILLE, NORDSTEDT, WILDEMAN, SAUVAGEAU,

DeToni, Chodat, Farlow, Arthur, Magnus, Saccardo, Patouillard, Jaczewski, Marshall-Ward, Vuillemin, Atkinson, Bresadola, Clements, Golenkin, Hua, Malmö, Zahlbruckner, Schiffner, Stephani, Levier, Evans, Cardot, Brotherus, Fleischer, Mrs. Britton, Salmon, and a few others whose names could not be secured. Some others could profitably be added to the list.

The entertainments, excursions, and visits to various institutions were numerous and attractive. A reception by the emperor was arranged, but the death of Grand Duke Josef on Tuesday estopped that, as well as a reception by the burgomeister at the Rathaus. Various long excursions after the Congress were provided, and all were sufficiently patronized to be undertaken.

The Committee of organization and the various local committees are to be congratulated on the success of their arrangements. These quinquennial international Congresses may now be considered a fixed feature of the botanical world.—C. R. B.

ANOTHER SEED-LIKE CHARACTERISTIC OF SELAGINELLA.

Two species of Selaginella (*S. rupestris* and *S. apus*) form embryos in the autumn which may resume growth after a period of rest. I left plants of these two species in a shallow box out of doors during the months of November and December, 1903. They were frozen and thawed several times during that time. In January the box was brought into the laboratory, the plants watered thoroughly, and allowed to thaw gradually. At the expiration of three or four days, the vegetative parts of the plants indicated a resumption of growth. Upon examining the strobili, young sporophytes were found thrusting roots and cotyledons from the female gametophytes. *Selaginella rupestris* is the species which displays a reduction in the number of megaspores, which are retained throughout germination, and even until the young sporophyte is well advanced.—Florence Lyon, *The University of Chicago.*

CURRENT LITERATURE.

BOOK REVIEWS.

North American Flora.

SUCH is the title of the most extensive systematic work hitherto undertaken in America. It is to contain all plants growing without cultivation in North America, which includes Greenland, Central America, Republic of Panama, and the West Indies, except Trinidad, Tobago, Curaçao, and other islands off the northern coast of Venezuela, whose flora is essentially South American. The work is published by the New York Botanical Garden, with Professors L. M. UNDERWOOD and N. L. BRITTON as the committee in charge. The names of the advisory committee are ATKINSON, BARNES, COULTER, COVILLE, GREENE, HALSTED, and TRELEASE.

The plans for such a publication have been under consideration for a number of years, and such large cooperation has been secured that there is every assurance of a completed work within a reasonable time. The plan includes the publication of thirty volumes, each to contain four or five parts; and in this way any part of any volume can be published as soon as it is ready. The volumes are assigned as follows: 1. Mycetozoa, Schizophyta, Diatomaceae; 2 to 10, Fungi; 11 to 16, Algae; 14 and 15, Bryophyta; 16, Pteridophyta and Gymnospermae; 17 to 19, Monocotyledones; 20 to 30, Dicotyledones.

The first fascicle has been issued recently,[1] dated May 22, 1905. Its typographical appearance gives abundant evidence of the great care that has been exercised in the selection of type and the arrangement of material. For example, the order with each species is the name and citation, description, type locality, distribution, and illustrations. The contents are as follows: J. K. SMALL gives a description of the order Rosales and a key to its twenty-four families; G. N. NASH presents Podostemonaceae, with five genera and ten species; N. L. BRITTON and J. N. ROSE contribute the Crassulaceae, occupying the bulk of the fascicle, twenty-five genera being recognized (*Oliveranthus*, *Corynephyllum*, *Cremnophila*, *Sedastrum*, and *Tetrorum* being new) and 284 species (twenty-nine being new); P. A. RYDBERG presents Penthoraceae, with its single genus and species, and Parnassiaceae, the single genus containing thirteen species, four of which are new.

The New York Botanical Garden and American botanists are to be congratulated upon the inception of this great work.—J. M. C.

[1] North American Flora. Vol. 22. Part 1. Rosales, JOHN KUNKEL SMALL. Podostemonaceae, GEORGE VALENTINE NASH. Crassulaceae, NATHANIEL LORD BRITTON, JOSEPH NELSON ROSE. Penthoraceae, Parnassiaceae, PER AXEL RYDBERG. 8vo. pp. 80. New York: The New York Botanical Garden. 1905. Subscription price $1.50 for each part.

Studies in general physiology.

THE APPEARANCE OF LOEB'S *Studies in general physiology*[2] should give new impetus to the already active research in regard to the factors which control vital phenomena. No one has emphasized more clearly the essential similarity existing between the protoplasms of the two kingdoms than has this writer, and the present work promises to be of great use to plant as well as to animal physiologists.

These two volumes, of the Decennial Series of the University of Chicago, bring together in reprint the list of brilliant contributions which gave to the author his prestige in protoplasmic physiology. They consist of thirty-eight papers, published through various channels and in two languages, between the years 1889 and 1902. These are arranged in the chronological order of their previous publication, beginning with those on tropisms and ending with those on artificial parthenogenesis and on the irritability of muscles. Some of them have been somewhat shortened by the omission of repetitions which are unnecessary in the collected series; those originally published in German have been excellently translated into English by Dr. MARTIN FISCHER, and considerable additional light has been thrown upon certain points by appended footnotes bearing the date 1903.

The author and the physiological world as well are to be congratulated upon the attractive form of the publication. The volumes are printed upon a good quality of paper, and in type which is easily read. Illustration is by means of very clear figures in the text, and the citations of literature are where they should be, namely at the base of the page on which reference is made.

The only cause for regret to be felt by the reader of these volumes comes from the thought of how much more valuable the work might have been had it but taken the form of a treatise on the physiology of protoplasm; for in such a form the author might not only have connected his ideas into a more available whole, but also would have been offered a better opportunity to give to the reader the benefit of his broader view of the suggestions arising therefrom.—B. E. LIVINGSTON.

NOTES FOR STUDENTS.

ITEMS OF TAXONOMIC INTEREST are as follows: F. S. EARLE (Bull. N. Y. Bot. Gard. **3**:289–312. 1905) has published 33 new species of West-American fungi and 19 new species of tropical (mostly Porto Rican) fungi.—J. K. SMALL (*idem* 419–440), under the title "Additions to the flora of subtropical Florida," has published new species in Stenophyllus, Limodorum, Quercus (2), Phytolacca, Aeschynomene, Linum (2), Polygala (4), Phyllanthus, Croton, Stillingia, Chamaesyce, Gaura, Proserpinaca, Adelia (2), Rhabdadenia, Jacquemontia, Heliotropium, Lantana, Verbena, Scutellaria, Ruellia, Ernodea, Melanthera, and Carduus.—P. A. RYDBERG (Bull. Torr. Bot. Club **32**:123–140. 1905), in his

[2] LOEB, JACQUES, Studies in general physiology. Part I, pp. xiii+423. Part II, pp. xi+425–782. Decennial Publications, The University of Chicago 1905.

14th paper entitled "Studies on the Rocky Mountain flora," has described new species in Machaeranthera (3), Xylorrhiza, Erigeron (7), Antennaria, Helianthus, Tetraneuris (2), Artemisia (3), Pyrrocoma, Tetradymia, Arnica, Carduus (5), Gaertneria, Crepis (5), Agoseris (5), and Taraxacum.—H. D. HOUSE (*idem* 139–140) has described two new species of Convolvulus from the western United States.—M. L. FERNALD and C. H. KNOWLTON (Rhodora **7**:61–67. *pl. 60.* 1905), in presenting *Draba incana* and its allies in northeastern America, have described two new species.—C. K. SCHNEIDER (Bull. Herb. Boiss. II. **5**:335–350. 1905) has published a synopsis of the species of Spiraea (Euspiraea), recognizing 57 and describing 8 as new.—G. LINDAU (*idem* 367–374), in his fourth paper on American Acanthaceae, has described a new genus (*Diateinacanthus*) from Honduras, and also 9 new species.—C. K. SCHNEIDER (*idem* 391–403, 449–464), in continuing his synopsis of Berberis, includes 53 species, 12 of which are new.—C. DECANDOLLE (*idem* 417–427) has published an account of the Meliaceae of Costa Rica, recognizing 23 species, 15 of which are described as new.—R. CHODAT (*idem* 481–506), in continuing his publication of Hassler's Paraguay collection, has described a new genus (*Aporosella*) and 16 new species of Euphorbiaceae.—A. W. EVANS (Bull. Torr. Bot. Club **32**:179–192. *pl. 5.* 1905) has described 3 new liverworts from Florida.—ALICE EASTWOOD (*idem* 193–218) has described new western species of Clematis, Aquilegia, Myosurus, Horkelia, Astragalus, Vicia (2), Lathyrus, Thermopsis, Rosa, Heuchera, Lithophragma, Jepsonia, Arctostaphylos (2), Cynoglossum, Cryptanthe, Phacelia, Polemonium, Pentstemon (6), Orthocarpus (4), Castilleia, Antirrhinum (2), Collinsia, Chrysoma (2), Raillardella, Hieracium, and Lessingia.—J. M. C.

PROTEID SYNTHESIS in developing peas forms the subject of a paper by ZALESKI.[3] In one series of expermients the ripening seeds were cut in halves and kept several days in either a dry atmosphere or one saturated with water. In either case the analyses of the seeds at the beginning and end of the experiments showed that there was an increase in the proteid content and a corresponding decrease in the content of asparagin, amido-acids, and hexon bases. When whole peas were used for the experiments, the analyses show that in place of the proteid increase there is a decrease, with the formation of crystalline nitrogenous derivatives. Experiments were carried out to determine whether or not the proteid synthesis was due to enzyme action. Finely ground developing peas were treated with solutions of ammonium sulphate or asparagin and allowed to stand with antiseptics for varying lengths of time. In all cases there was a decrease in proteid content followed by a slight increase. In none of the tests did the final quantity of proteid nitrogen equal that at the beginning of the experiment.

ZALESKI's study of the proteid changes in ripening seeds showed that these

[3] ZALESKI, W., Beiträge zur Kenntniss der Eiweissbildung in reifenden Samen. Ber. Deutsch. Bot. Gesells. **23**:126–132. 1905.

organs contained proteolytic enzymes, and in a second paper[4] he gives the results of his study of the protease in ripening peas. Autodigestion experiments were carried out with freshly ground developing peas, with a powder prepared by drying the tissues at 35–37° C., and with a powder made from ground peas in a manner analogous to ALBERT'S acetone method for making zymase preparations from yeast. Evidence of proteolytic activity was furnished by analyses showing a diminution of the proteid as the digestions progressed. The enzymes of peas in the earlier stages of development caused a much more active proteolysis than those from the seeds in more advanced stages. This greater vigor of the enzyme of younger tissues is brought out in experiments showing the influence of strong sugar solution and of potassium nitrate. These agents had little effect on the progress of autodigestion with young peas, but caused a noticeable inhibition in the tests with older ones. The proteolysis is hurried by the presence of a trace of alkali, but retarded by stronger alkalis and by acids. The optimum temperature lay between 40 and 50° C. The enzyme acted vigorously on Witte peptone.—ARTHUR L. DEAN.

MISS TAMMES[5] has tested the sensibility to differences of environment of several fluctuating characters in each of several species grown under more and less favorable soil conditions. Of the fifteen characters studied, fourteen agree with the experience of others who have studied the influence of nutrition on fluctuation, in showing a shifting of the curves to the left when the plants are grown on poor soil; but, as would have been expected, the corresponding characters in the different species and the different characters in the same species show considerable differences of sensibility, some being relatively stable, others showing a very marked response to changed conditions. As a measure of variability, the author follows VERSCHAFFELT in using the quartile (Q) divided by the mean instead of the standard deviation (σ) divided by the mean, which is used by English and American biometers. In comparing the sensibility she employs a new measure, the "sensibility-coefficient," which is the difference between the well-fed and poorly-fed plants with reference to the character in question, divided by the condition in the well-fed. It is obvious that this measure can be of use only in allowing the comparison of different characters in a single series of observations such as those presented, and not as an absolute measure of sensibility which would permit comparison with the sensibility-coefficients for the same characters under other conditions. In the well-fed plants the coefficients of variability for all the characters of a given species were found to be nearly alike, though the several species differed markedly from each other in this regard; but in the poorly-fed plants the variability of the several characters was very differently affected, being sometimes increased sometimes decreased.

[4] ZALESKI, W., Zur Kenntniss der proteolytischen enzyme der reifenden Samen. Ber. Deutsch. Bot. Gesells. **23**: 133–141. 1905.

[5] TAMMES, TINE, On the influence of nutrition on the fluctuating variability of some plants. Koninklijke Akad. Wetens. Amsterdam **7**: 308–411. *pl. 1.* 1905.

Miss TAMMES[6] has also studied the periodicity in the occurrence of supernumerary leaflets in *Trifolium pratense quinquefolium* DeVries. She finds that there are two concurrent anomalies, namely, a division of the lateral leaflets and a division of the terminal leaflet. The former is much the more frequent and reaches its maximum development below the middle of the primary branches, while the latter reaches its maximum also on the primary stems but on the upper half near the inflorescence. Few supernumerary leaflets occur on branches of second, third, and fourth orders.—G. H. SHULL.

LUXBURG[7] has presented some experimental data and a very able discussion to show that our views of the distribution of growth in geotropically stimulated organs, based largely on the experiments of SACHS, are no longer tenable. After applying more approved methods in a reinvestigation of the results obtained by SACHS and NOLL especially, he finds it no longer permissible to regard any position as leaving the organ insensible to the geotropic stimulation. The thesis maintained by NOLL that the normal vertical position of an organ furnishes it a condition of indifference to geotropic stimulation is regarded by the author as a striking example of the overestimation of the value of curvature reactions as indicators of the perception of stimulation by gravitation. The absence of a curvature response by no means implies that the stimulus is not perceived. HERING'S results with inverted organs are regarded as rendering a perception in the erect position very probable; the absence of a curve means merely that an asymmetrical growth was not induced. The author advances the theory that geotropic curvatures are accomplished by two different but as yet not separately observed processes, whose concurrent operation involves an alteration in the rate of growth and an asymmetrical distribution of growth. That favorable objects may be found in which these two processes ordinarily combined may be separately observed is regarded as not impossible. The theory advanced is supported chiefly by the study of organs for which a resumption growth is a prerequisite to curvature. The reaction of organs in the position of normal equilibrium, in which case a curvature does not appear, is to be distinguished from that in which curvature does occur merely by this, that an asymmetrical distribution of growth necessary to produce the curve is not induced.—RAYMOND H. POND.

CORRENS[8] has published ten letters written by GREGOR MENDEL to CARL NÄGELI during the period of MENDEL'S greatest activity in the study of hybrids (1866–1873). NÄGELI was the recognized authority on Hieracium hybrids in nature, and MENDEL wrote him careful accounts of the progress of his experi-

[6] TAMMES, TINE, Ein Beitrag zur Kenntn'ss von *Trifolium pratense quinquefolium* DeVries. Bot. Zeit. **62**: 211–225. 1904.

[7] LUXBURG, GRAF. H., Untersuchungen über den Wachstumsverlauf bei der geotropistischen Bewegung. Jahrb. Wiss. Bot. **41**: 309–457. 1905.

[8] CORRENS, C., Gregor Mendel's Briefe an Carl Nägeli 1866–1873. Ein Nachtrag zu den veröffentlichten Bastardierungsversuchen Mendels. Abhandl. Math.-Phys. Dasse Sächsischen Gesellls. Wiss. **29**: 189–265. 1905.

ments, and also sent him much of his artificially produced hybrid material, particularly of Hieracium. The letters were written with great care, and as they report many hybrids that were not mentioned in MENDEL'S published works, they are an important addition to the literature of hybridization. CORRENS has carefully annotated the letters and added two appendices, in the first of which he discusses the bearing of parthenogenesis upon MENDEL'S results in Hieracium, pointing out that these letters can leave not the slightest doubt that true hybrids were secured, but inferring from the constancy of the hybrid forms in successive generations that there is no reduction division, and that consequently, following STRASBURGER, we should speak of apogamy rather than parthenogenesis in Hieracium. In the second appendix CORRENS considers the question whether sexual characters are inherited according to MENDEL'S principles, such a possibility having been suggested in one of these letters. After examining the various possible assumptions as to dominance and the purity or the hybrid character of the gametes with respect to sex, he concludes that sex-determinants are fundamentally unlike the ordinary character-units and incapable of being satisfactorily explained by the laws of dominance and the segregation of parental gametes.—G. H. SHULL.

LEWIS[9] has investigated the development of *Phytolacca decandra*, his main purpose being to follow the origin and fate of the endosperm, with special reference to its behavior during germination. The development of the microsporangium follows the usual course, the tapetal cells perhaps deserving mention in that they sometimes contain six nuclei, the average number being four. In the megasporangium one and sometimes two archesporial cells appear, and a tapetal cell is cut off. The endosperm grows rapidly, "forming a sac with a great central vacuole." The nuclei lie free in the cytoplasm of the endosperm and always divide amitotically. The embryo sac finally becomes the extensive cavity characteristic of campylotropous ovules. Walls later begin to appear in the micropylar endosperm, the cells encroach on the central cavity, and finally the endosperm is completely cellular except for a mass of cytoplasm at the chalazal end of the sac. The embryo in its early stages consists of a well-developed suspensor and a many-celled, undifferentiated, spherical embryo. Starch is observed to accumulate in the perisperm, notably next to the concavity of the curved embryo, which disorganizes the endosperm almost completely. In germination the embryo elongates, and the radicle is pushed through the endosperm cap and the seed coat. The cotyledons continue to elongate until the stem tip is free, and the cells of the thick endosperm cap remain turgid, persisting "as a thick ring of tissue clasping the bases of the cotyledons and stopping the opening made in the seed coat at germination."—J. M. C.

[9] LEWIS, I. F., Notes on the development of *Phytolacca decandra* L. Johns Hopkins Univ. Circ. No. 178. pp. 35–43. *pls.* 3. 1905.

NEWS.

J. FRANKLIN COLLINS has been appointed assistant professor of botany at Brown University.

DR. KARL FRITSCH has been appointed professor of systematic botany at the University of Graz.

DURING the last year 59,349 specimens were added to the Herbarium of the New York Botanical Garden.

PROFESSOR ADOLF ENGLER will attend the meeting of the British Association in South Africa, whence he goes to East Africa for further study of the flora.

DR. RICHARD SADEBECK, professor of botany and director of botanical museums at Hamburg, and well known for his work on pteridophytes and plant diseases, died recently at the age of 64 years.

J. N. ROSE left Washington June 21 for the "cactus fields" of southern Mexico, expecting to be gone about four months. His purpose is to collect not only herbarium specimens, but also material preserved in formalin and living plants.

AT THE JUNE CONVOCATION, the University of Chicago conferred the degree of Ph.D. upon H. HASSELBRING, the title of the thesis being "Carbon assimilation;" and upon ETOILE B. SIMONS, the title of the thesis being "A morphological study of *Sargassum filipendula*."

THE BOTANICAL SUBJECTS for the two annual Walker prizes in 1906 are as follows: An experimental field study in ecology, A contribution to a knowledge of the nature of competition in plants, A physiological life history of a single species of plants, and Phylogeny of a group of fossil organisms.

P. PORSILD, the Danish botanist, has secured the establishment of a biological station on the island of Disco, western Greenland, latitude 70°. The necessary 35,000 kroner (about $9500) was given by Justitsraad HOLCK, of Copenhagen, and the Danish government has promised maintenance.